GEOTHERMAL EXPLORATION & DEVELOPMENT CORP.

PACIFIC OPERATIONS

July 10, 1978

Mr. William Y. Thompson
Chairman of the Board
Department of Land and Natural Resources
P. O. Box 373
Honolulu, Hawaii 96809

Reference: Application for Mining Lease Under HRS 182.5
by Puuwaawaa Steam Co. (STEAMCO)

Gentlemen:

Attached for your consideration is our application for a Mining Lease prepared in accordance with Rule 5 of the Rules and Regulations outlining procedures for leasing of Reserved Lands, possessed by an occupier holding a General Lease from the State as defined in HRS 182.1. The applicant is a partnership known as Puuwaawaa Steam Co. (STEAMCO) in which Geothermal Exploration & Development Corp. (GEDCO) is the general partner, and F. Newell Bohnett is the principal limited partner. The application package conforms to requirements of Rule 4.1, 4.2, 4.5 & 4.6 of the Geothermal Rules and Regulations and includes the following:

1. One hundred dollar ($100.00) check for filing fee.
2. An accurate description and map of the land for which geothermal lease is being requested.
3. Geological and geophysical report of the findings supporting evidence of a potential geothermal resource requiring further exploration and ultimate development if discovery is made.
4. Preliminary plan for exploration and development.
5. Environmental assessment relating to the impact from geothermal exploration and development.
6. Certificate of applicant's qualifications for holding a geothermal mining lease, and evidence of signing officer's authority to enter into agreement with the State of Hawaii, and certifying that the acreage applied for does not exceed permissible limitations as per Rule 3.10.

7. Narrative supporting justification for approval of negotiating a mining lease with applicant, under HRS 182.5, without Public bidding.
8. Copy of assignment of occupier's rights to applicant.

Very truly yours,

PUUWAAWAA STEAM CO.

By: E C Craddick

E. C. Craddick, President
Geothermal Exploration & Development Corp.
(General Partner)

By: F. Newell Bohnett

F. Newell Bohnett, Owner
Puuwaawaa Ranch
(Limited Partner)

ECC/sm
Enclosures

CONFIDENTIAL

APPLICATION FOR MINING LEASE

UNDER HRS 182.5

BY

PUUWAAWAA STEAM CO.

JULY, 1978

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MINERAL RIGHTS APPLICATION

Portion of Government Lands of
Puuwaawaa and Puuanahulu
North Kona, Hawaii

Beginning at a point at the northeast corner of this parcel of land, the coordinates of said point of beginning referred to Government Survey Triangulation Station "Puuwaawaa" being 16,865.66 feet North and 766.02 feet East and running by azimuths measured clockwise from true South:

1.	340° 40' 30"	15,500.00	feet along the remainder of the land of Puuanahulu;
2.	40° 15'	6,180.00	feet along the remainder of the lands of Puuanahulu and Puuwaawaa;
3.	70° 40' 30"	9,138.65	feet along the remainder of the land of Puuwaawaa;
4.	160° 40' 30"	14,778.70	feet along the remainder of the land of Puuwaawaa to a point at the southerly side of Hawaii Belt Road (F.A.P. 10-A);
5.	250° 40' 30"	3,340.10	feet along the southerly side of Hawaii Belt Road (F.A.P. 10-A); thence along the southerly side of Hawaii Belt Road (F.A.P. 10-A) along a curve to the right having a radius of 1575.00 feet, the chord azimuth and distance being:
6.	252° 50' 30"	119.09	feet;
7.	255° 00' 30"	1,460.60	feet along the southerly side of Hawaii Belt Road (F.A.P. 10-A); thence along the southeasterly side of Hawaii Belt Road (F.A.P. 10-A) along a curve to the left having a radius of 1025.00 feet, the chord azimuth and distance being:
8.	241° 59' 30"	461.73	feet;
9.	228° 58' 30"	2,465.5	feet along the southeasterly side of Hawaii Belt Road (F.A.P.); thence along the southeasterly side of Hawaii Belt Road (F.A.P. 10-A) along a curve to the right having a radius of 975.00 feet, the chord azimuth and distance being:
10.	235° 56'	236.24	feet;

Murray, Smith & Associates, Ltd.
REGISTERED SURVEYORS
P. O. BOX 863 HILO, HAWAII OFFICE PHONE 935-9725

11.	242° 53' 30"	357.4	feet along the southeasterly side of Hawaii Belt Road (F. A.P. 10-A); thence along the southeasterly side of Hawaii Belt Road (F.A.P. 10-A) along a curve to the left having a radius of 2025.00 feet, the chord azimuth and distance being:
12.	239° 24'	246.66	feet;
13.	235° 54' 30"	678.60	feet along the southeasterly side of Hawaii Belt Road (F. A.P. 10-A); thence along the easterly side of Hawaii Belt Road (F.A.P. 10-A) along a curve to the left having a radius of 425.00 feet, the chord azimuth and distance being:
14.	171° 46'	764.89	feet;
15.	107° 37' 30"	91.80	feet along the easterly side of Hawaii Belt Road (F.A.P. 10-A); thence along the easterly side of Hawaii Belt Road (F.A.P. 10-A) along a curve to the right having a radius of 325.00 feet, the chord azimuth and distance being:
16.	132° 53' 30"	277.44	feet;
17.	158° 09' 30"	135.90	feet along the easterly side of Hawaii Belt Road (F.A.P. 10-A); thence along the easterly side of Hawaii Belt Road (F.A.P. 10-A) along a curve to the right having a radius of 325.00 feet, the chord azimuth and distance being:
18.	171° 14' 30"	147.14	feet;
19.	184° 19' 30"	38.0	feet along the easterly side of Hawaii Belt Road (F.A.P. 10-A); thence along the easterly side of Hawaii Belt Road (F.A.P. 10-A) along a curve to the left having a radius of 275.00 feet, the chord azimuth and distance being:
20.	168° 29' 54"	150.00	feet;
21.	315° 26' 30"	266.51	feet along Grant 5794 to John Kahaikapuna, Puu Anahulu Homesteads;

22.	318° 38' 30"	327.00	feet along Grant 5794 to John Kahaikapuna, Puu Anahulu Homesteads;
23.	301° 29' 30"	628.00	feet along Grant 5794 to John Kahaikapuna, Puu Anahulu Homesteads;
24.	305° 05' 30"	380.00	feet along Grant 5794 to John Kahaikapuna, Puu Anahulu Homesteads;
25.	298° 47' 30"	703.00	feet along Grant 5794 to John Kahaikapuna, Puu Anahulu Homesteads;
26.	213° 44' 30"	3,796.00	feet along Grant 5794 to John Kahaikapuna, Grant 8521 to Joseph Kaholo, Grant 5913 to Lizzie Alapai, Grant 8520 to Louisa Keawe, Grant 8559 to Henry Hao and Grant 9990 to Frank Coelho, Puu Anahulu Homesteads;
27.	213° 52' 30"	1,205.51	feet along Grant 6147 to Kalani Nakupuna to the point of beginning and containing a GROSS AREA of 5,032.77 Acres and a NET AREA of 5,000.00 Acres, after deducting area of Fee Simple parcels covering Grants 6266, 4862, 5344 and S-13704.

MURRAY, SMITH & ASSOCIATES, LTD.

By Donald James Murray
Donald James Murray
Registered Surveyor

Hilo, Hawaii
June 5, 1978

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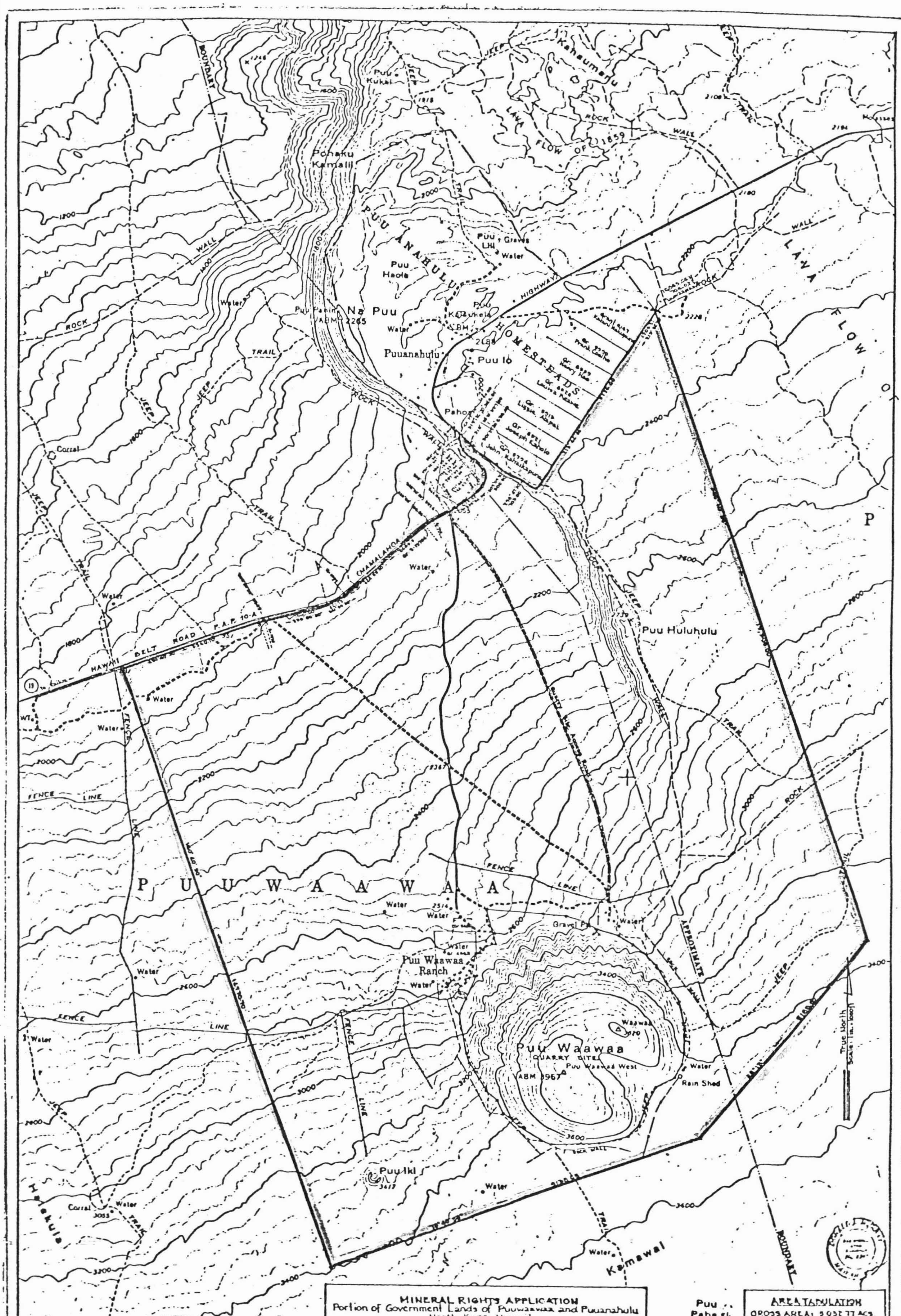

MINERAL RIGHTS APPLICATION
Portion of Government Lands of Puuwaawaa and Puuanahulu
North Kona, Hawaii
Plan by Murray, Smith & Associates, Ltd
P.O. Box 663
Hilo, Hawaii
AREA TABULATION
GROSS AREA:
Less:
NET AREA:
P U U W A A W A A
Puu Waawaa
QUARRY SITE
Puu Waawaa Ranch
Puu Huluhulu
Puuanahulu
Na Puu
PUU ANAHULU HOMESTEADS
Pohaku Kamalii
Puu Kukai
Kahaumanu
LAVA FLOW OF 1859
LAVA FLOW OF
HAWAII BELT ROAD F.A.P. 10-A
HIGHWAY
MAMALAHOA
Puu Iki
Kamawai
Puu Pahaei
Puu Haole
Puu Io
Pahoa
FENCE LINE
ROCK WALL
JEEP TRAIL
BOUNDARY
Rain Shed
Gravel Pit
Corral
Water

THE PUU WAAWAA GEOTHERMAL PROSPECT
(Hawaii County)

Report of Geophysical Investigations

June 1, 1978

THE PUU WAAWAA GEOTHERMAL PROSPECT

Introduction

The island of Hawaii is built up from five shield volcanoes; these are Kilauea, Mauna Loa, Hualalai, Mauna Kea, and Kohala, in order of increasing age. Of the five volcanoes, three, icluding Kilauea, Mauna Loa, and Hualalai, have been active in historic time. Even the oldest, Kohala, appears to have been active as recently as 300,000 years ago. Because of the youth of the volcanoes on Hawaii, any or all may have commercially exploitable geothermal systems associated with them.

The locations of the five volcanoes and the surface geology are shown on the map in Figure 1. On this map, the historic flows are shown in red.

Until now, most of the effort in geothermal development has been concentrated on Kilauea volcano, with two geothermal test wells having been drilled. The first was located at the National Park at the summit of Kilauea volcano. The test well was drilled under the sponsorship of the National Science Foundation as a research project to learn about the potential for the existence of goethermal reservoirs in volcanic rocks of the type found in Hawaii. Temperatures of about 300 F were found at depths of about 4000 feet. The rate of increase of temperature with depth in the hole indicated that temperatures of 500 to 600 F would probably be present at depths between 5000 and 6000 feet. Because geothermal production was not desired from a

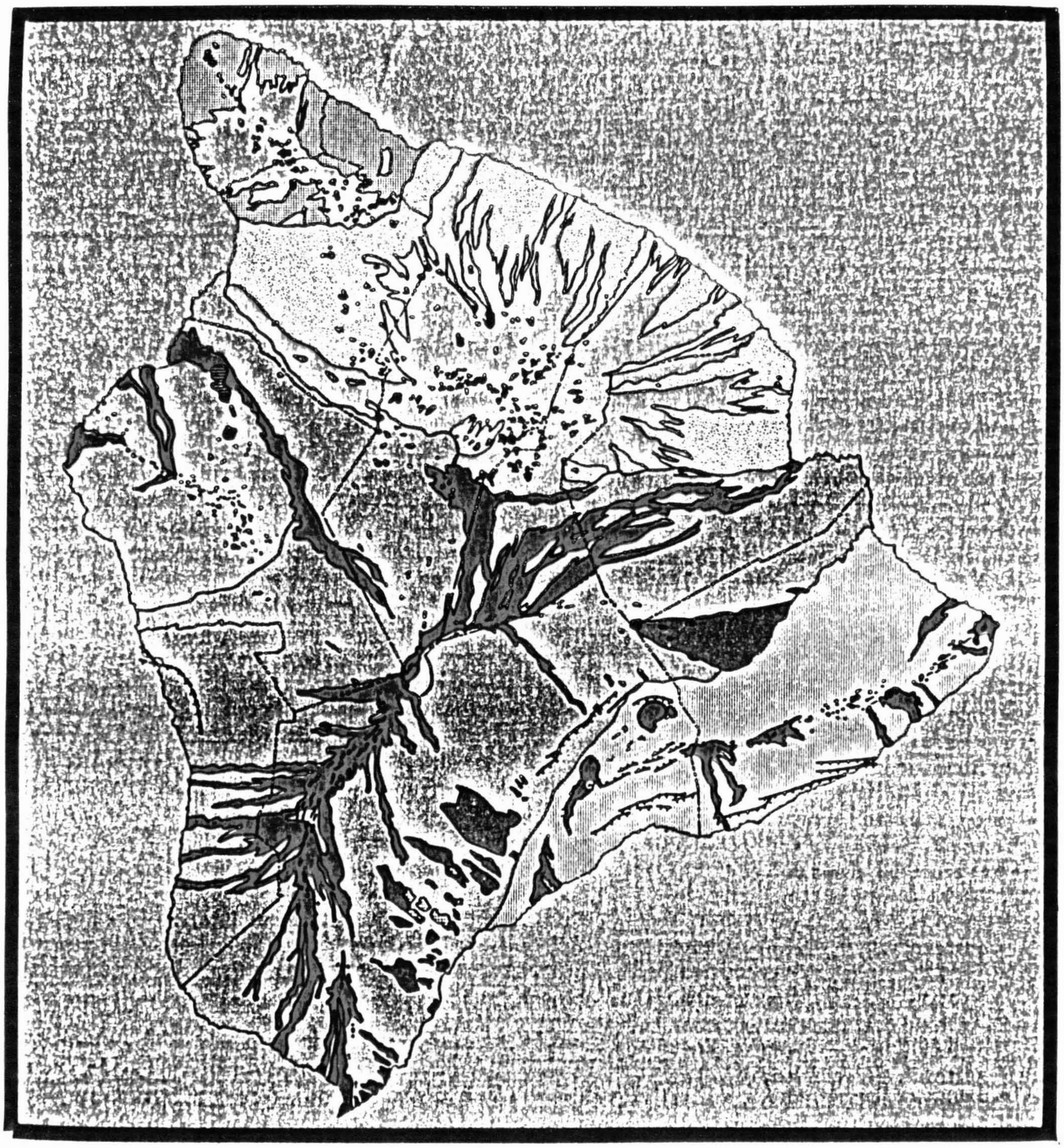


Figure 1. Generalized geologic map of the island of Hawaii (from Atlas of Hawaii, University of Hawaii Press, 1973). Historic flows are shown in red, cinder cones in black, differentiated flows in blue, and tholeitic flows in shades of green.

well located in a National Park, drilling was not carried past 4200 feet.

A second test well was drilled by the University of Hawaii in the Puna area of Kilauea Volcano under the sponsorship of the Energy Research and Development Administration. This well was taken to a total depth of slightly more than 6000 feet. The bottom hole temperature is about 600 F.

In view of the success met in drilling at Kilauea Volcano, it appears that development of geothermal energy for electrical generation will take place within a few years. Energy produced in Puna will find a market primarily in the Hilo area. There is need for additional electrical generating capacity on the Kona coast, and so, geothermal potential along the west coast of Hawaii has been reviewed to find the most suitable location for development. In terms of access, proximity to market, and geological setting, the north slope of Hualalai volcano, and particularly the area around Puu Waawaa, appears to offer promise. Some geological and geophysical exploration has been carried out to define a site for drilling a temperature test hole; this report describes the results which have been obtained to date. Studies carried out include an electrical resistivity survey done using the magnetotelluric method, a survey for soil mercury content, a self potential survey, shallow resistivity soundings using the Schlumberger method, and a review of historical seismicity in the area.

Geologic Setting

The volcanoes which make up the Hawaiian Archipelago are not identical in history, but show considerable similarity in the stages of development they have gone through. Initially, a shield volcano is built up by flows issuing from linear fractures or rifts. These flows are usually described as "primitive" basalts, or molten rock which is highly fluid. This primitive basalt flows forth in thin sheets, rapidly losing its heat to the air or ocean. In a matter of a hundred thousand years or so, the main part of the volcano builds up to the surface of the sea. Because of the rapid loss of heat from the extruded flows, a volcano in its primitive stage may not have much potential for development of geothermal reservoirs at depth.

As the building of a volcanic shield approaches its climax, eruptive activity commonly becomes centralized about a single volcanic center, rather than continuing along a rift zone. A complex stockwork of intrusive dikes forms beneath the main peak of the volcano. Often, the summit of the volcano collapses into the magma chamber formed by these dikes, leading to the development of a summit caldera, or crater. This central stock may have a diameter ranging from a few miles to more than ten miles. The stockwork and associated features represents a concentration of heat that offers considerable potential for the development of geothermal energy.

Finally, the principal eruptive phase of a shield volcano comes to an end. Magma is no longer replenished from deep in the earth. The residual magma left in the central magma chamber cools in place. As this cooling progresses, some minerals crystallize out, leaving the chemistry of the melt somewhat different in character from that of a primitive magma. This differentiated magma may erupt at rare intervals, forming cinder cones. The cooling phase of a magma chamber may take much longer than the original development of the primitive shield volcano. All during the differentiation phase, vast quantities of heat are present in the stock of the volcano, making a very favorable set of circumstances for the development of geothermal energy. After a half to one million years, the central stock may be cooled to the point where development is no longer practicable, but up until that time, the central part of the volcano is an excellent geothermal prospect.

On the island of Hawaii, both Kilauea and Mauna Loa volcanoes are in the primitive state, though both have developed to the point of formation of a central stock and a summit caldera. Mauna Kea, Kohala, and Hualalai have progressed to the final stage of erupting differentiated lavas.

Hualalai Volcano lies on the west coast of Hawaii, in the district of North Kona (see Figure 2). The present shield of Hualalai volcano was formed from eruptions along a

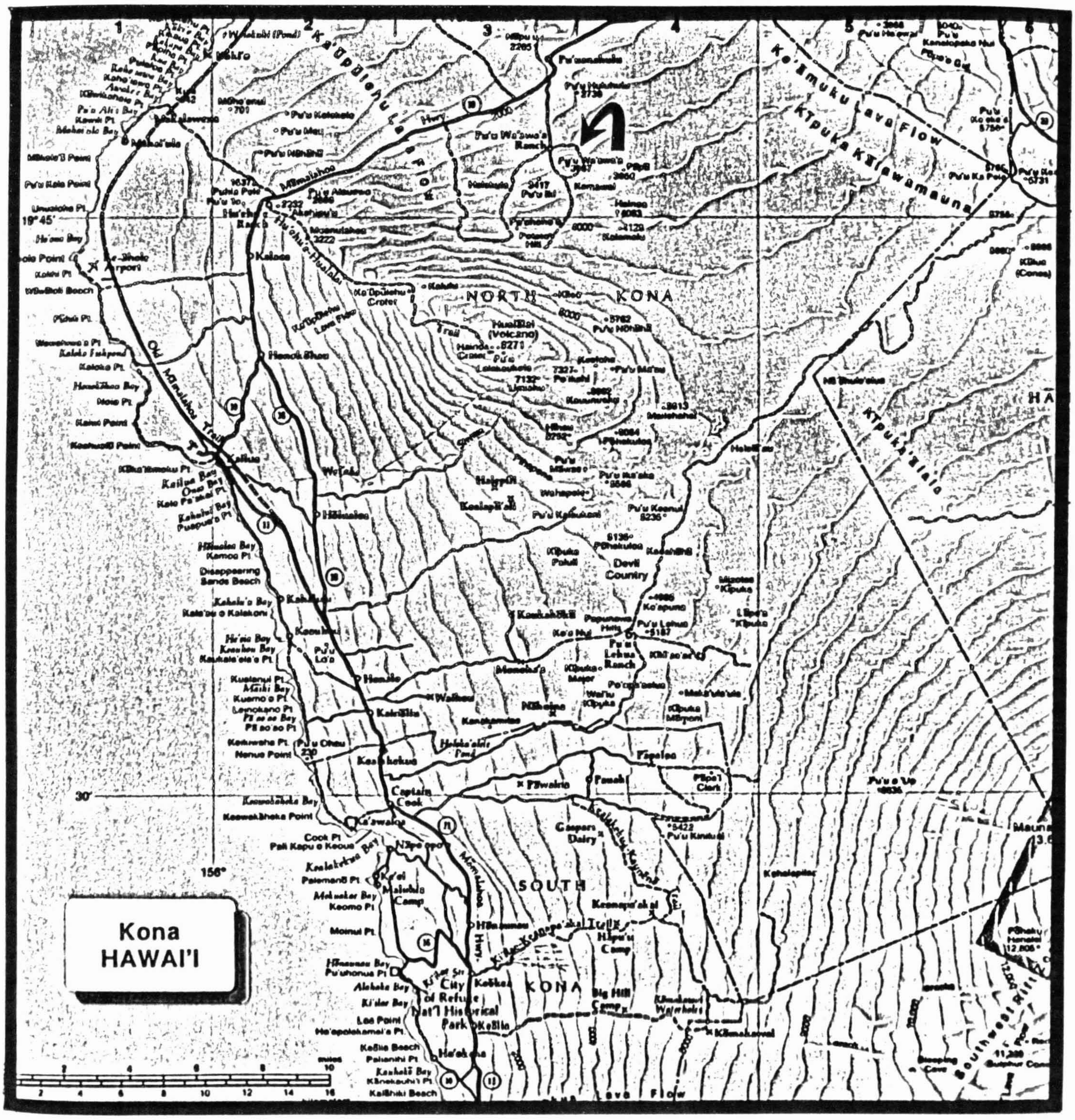


Figure 2. Geography and Topography of Hualalai Volcano, island of Hawaii (from Atlas of Hawaii, University of Hawaii Press, 1973).

rift zone trending N50 W - S50 E. The summit elevation is 8271 feet. A less well defined rift zone extends nearly north-south, about three miles east of the summit. More than 100 small cinder and spatter cones are scattered along these two rift zones. The last eruptive activity of Hualalai occured in 1800-1801. These flows issued from the NW-SE rift zone, as indicated on Figure 1.

Puu Waawaa, a large cone of Trachyte pumice more than a mile in diameter, is located on the north slope of Hualalai, about six miles from the summit. The Puu Waawaa trachyte represents a stage of magmatic differentiation far more advanced than that of any other rock of Hualalai volcano. The cone lies squarely on the N-S rift zone of Hualalai, and is more than 20 miles distant from the nearest other occurences of trachyte, which are located on Kohala Volcano. The Puu Waawaa trachyte is said by MacDonald and Abbott (1970) to have been formed by differentiation in a relatively small magma chamber belonging to Hualalai.

There are numerous small collapse craters along the summit of Hualalai, but no caldera. The gravity map of the island of Hawaii shows no gravity high at the summit, as one would expect over an intrusive stock. The nearest high is several miles to the southeast from the summit.

A rainfall map for the island of Hawaii is shown in Figure 3. The south face of Hualalai receives as much as 70 inches of rain per year, but the rainfall on the north face is relatively light.

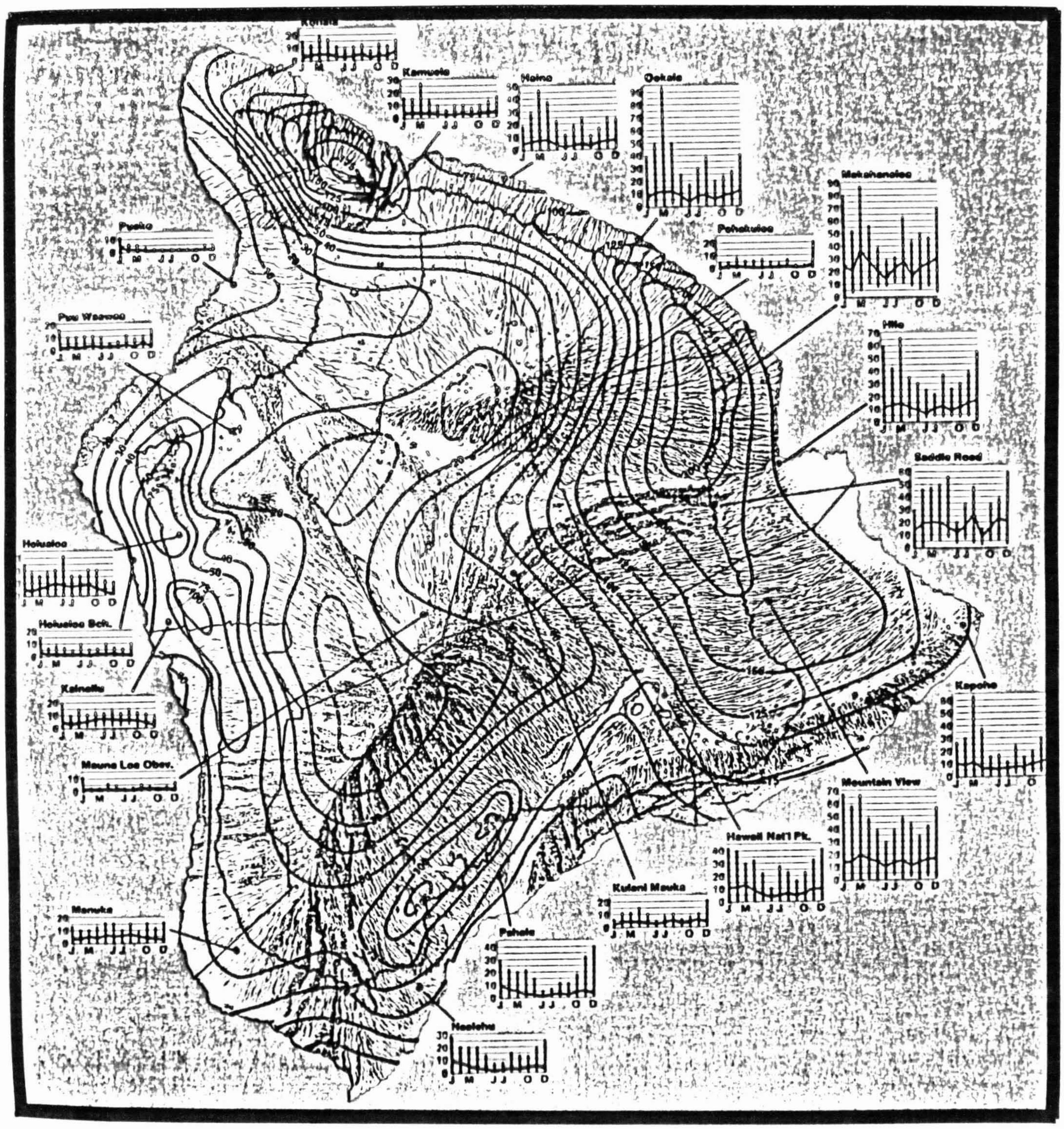


Figure 3. Rainfall statistics for the island of Hawaii (from Atlas of Hawaii, University of Hawaii Press, 1973).

A detailed map of the surface geology of Hualalai is shown in Figure 4. The pink areas represent the part of the Volcano covered by primitive basalt flows, with the red areas being the spatter cones, cinder cones, and pit craters from which these flows have emerged. The flow of 1800-1801 is shown in blue. The trachyte of Puu Waawaa and its associated flows are shown in lavender.

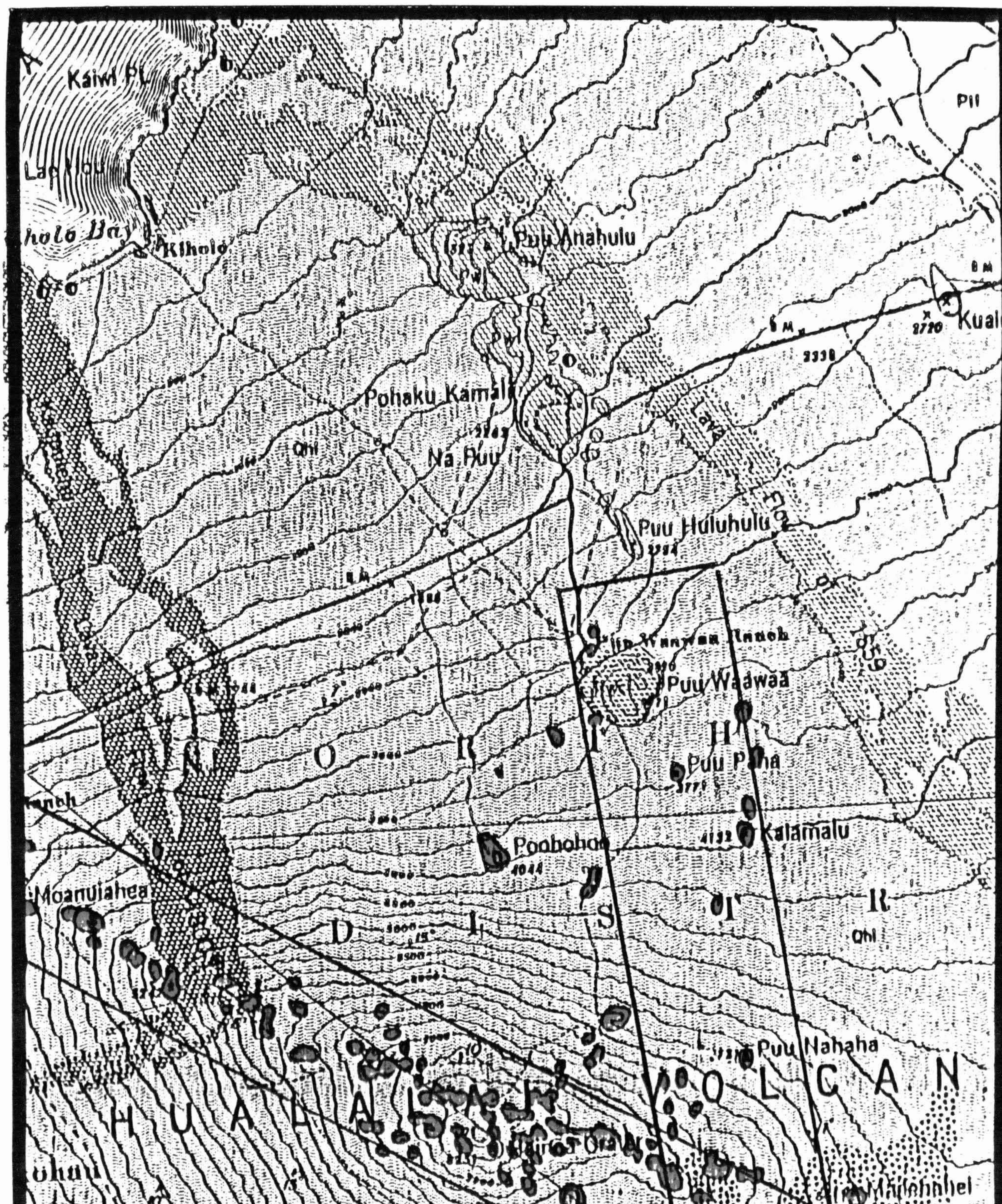


Figure 4. Surface geology of the Puu Waawaa area. Historic flows are shown in blue, Hualalai flows in pink, cinder cones in red, Puu Waawaa trachyte in lavender, and Mauna Loa flows in green. The two rift zones of Hualalai are outlined in black.

Magnetotelluric Survey

In August, 1977, a magnetotelluric survey of portions of the island of Hawaii was carried out to provide information about geothermal prospects in Puna, near the summit of Mauna Kea, and on the north slope of Hualalai volcano. The results of this survey have been described in an earlier report, but the data from Hualalai will be reviewed here.

The magnetotelluric method is a method for measuring earth resistivity that has come into wide use in geothermal prospecting. The electrical resistivity of rocks is lowered significantly at high temperatures, and so, any method of recognizing rocks with anomalously low resistivity will serve as an indirect means for locating a geothermal reservoir. Most methods for measuring earth resistivity require the injection of considerable amounts of electrical current into the ground. This may require bulky and cumbersome generating equipment. To avoid this problem, the magnetotelluric method makes use of naturally existing electromagnetic fields as an energy source. No source equipment is necessary, but the natural fields are weak, and very sensitive equipment is required to detect the effects of earth resistivity variations on these natural fields.

In the theory for the magnetotelluric method, it is considered that variations in the earth's magnetic field induce current flow in the earth, with the amount of current induced depending both on the strength of the magnetic field variation and the resistivity of the earth. It is necessary to measure both the amount of current flowing in the earth and the intensity of the magnetic field inducing it in order to compute resistivity. Moreover, since the directions of the magnetic field and the induced currents are unknown, measurements must be made in at least two directions to be sure that the two quantities are measured accurately.

The magnetic field components were measured in the survey of August, 1977, using a sensitive cryogenic magnetometer. The electric fields caused by current flow were detected with short electrode spreads (separation of 250 meters) oriented at right angles to one another. The four measured quantities -- two magnetic field components and two voltages from the electrodes -- were recorded graphically on a strip chart recorder. An example of a short recording from the HGP-1 site (the University of Hawaii well in Puna) is shown in Figure 5. On this illustration, the horizontal scale is time. The chart travel speed is one centimeter (the distance between vertical lines) per ten seconds. The two magnetic field components are recorded in red and violet, with the scale being approximately 100 milligammas per inch. The yellow and blue traces indicate the variations in electric field strength, with a recording sensitivity of approximately 500 microvolts per kilometer per inch of record deflection.

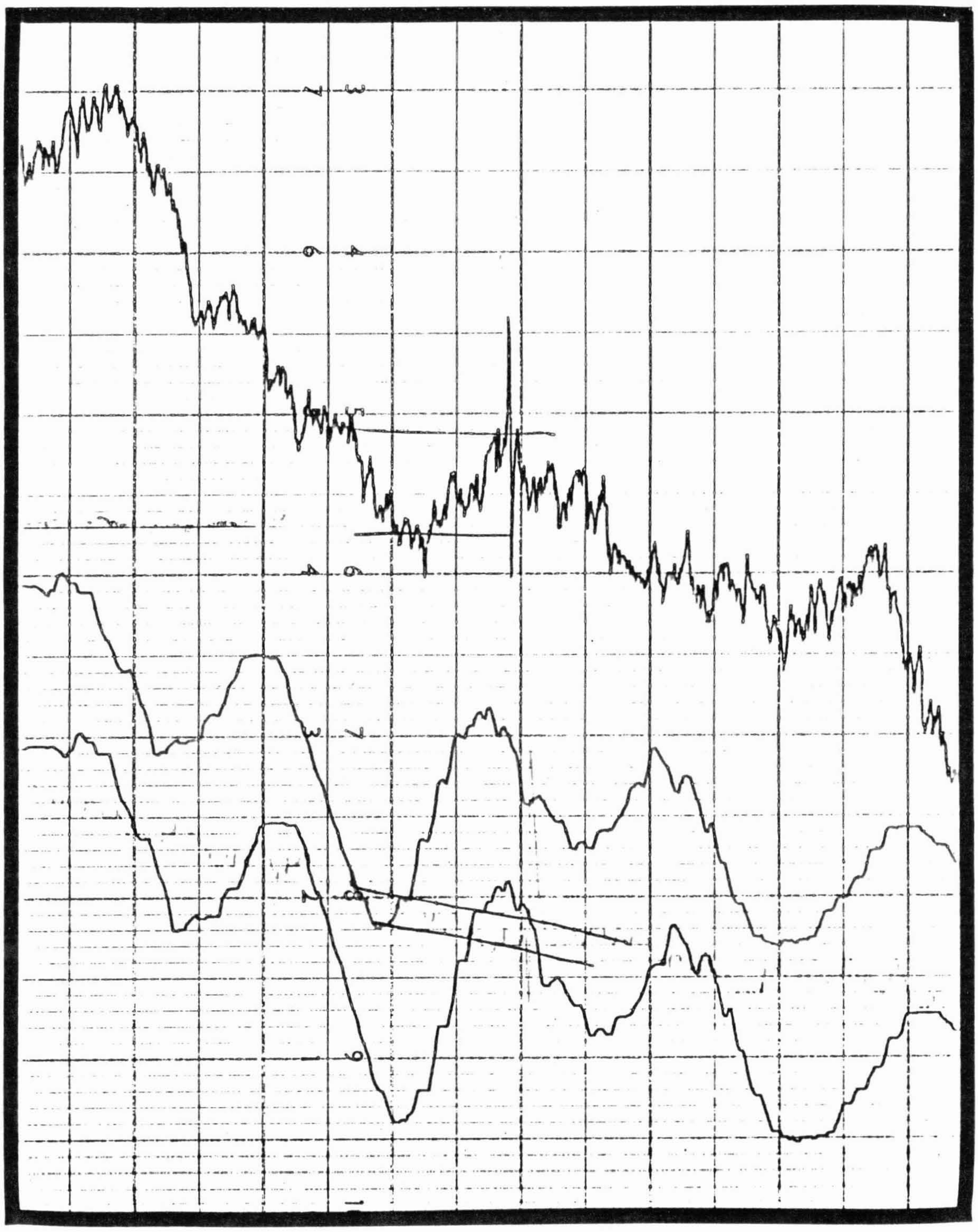


Figure 5. Portion of a magnetotelluric record obtained at the HGP-1 well site in Puna. The red and purple traces represent magnetic field traces, and the yellow and blue traces represent electric field traces.

In converting data such as those shown in Figure 5 to values of resistivity, the following procedure was used. An oscillation was picked on the record for which amplitudes for each of the four quantities could be determined. Then, the magnitude of the magnetic field and of the electric field was computed by vector addition of the measured components. The apparent resistivity was computed using Cagniard's formula:

$$\rho_a = 0.2\, T \left(\frac{E}{H}\right)^2$$

where T is the period of the oscillation in seconds, E is the magnitude of the electric field in microvolts per kilometer, and H is the magnitude of the magnetic field oscillation in milligammas. For the example shown in Figure 5, the magnitude of the magnetic field is 305 milligammas, the magnitude of the electric field is 408 microvolts per kilometer, and the period of the oscillation is 40 seconds. Cagniard's formula gives an apparent resistivity value of 14.3 ohm-meters.

The procedure described in the last paragraph provides an apparent resistivity value only for the dominant frequency on the record. The change in apparent resistivity with frequency is necessary to determine how true resistivity varies with depth in the earth. However, because this survey was carried out as a reconnaisance, no effort was made to obtain records that could be processed to provide data over a spectrum of frequencies. One additional computation was carried out, that of determining apparent conductance under the assumption that the geological section can be represented electrically as consisting of relatively conductive rocks over a resistant basement zone. In this case, the conductance of the surficial rocks, defined as the ratio of thickness to resistivity, can be computed simply from measurements made at one frequency. The formula for this computation is:

$$S_a = \left(\frac{T}{2\pi\mu\rho_a} \right)^{1/2}$$

where μ is the magnetic permability, taken to be that of free space, and ρ_a is the apparent resistivity computed from the Cagniard formula. For the HGP-1 site, the apparent value of conductance is 995 mhos.

Measurements were attempted at 62 sites, most of them in the vicinity of three prospects; Puna, Mauna Kea, and Hualalai. The locations of the Hualalai stations are shown on Plate 1, and Figure 6. On Figure 6, the data are superimposed on the geologic map of Hualalai volcano. Individual values for the apparent resistivity and apparent conductance are listed in Table 1.

The map on Plate I shows a striking feature in that a belt of high conductance values is present on the north slope of Hualalai volcano. The location of the belt is coincident with the north-south trending rift zone of Hualalai. The highest conductance was observed at station 49, immediately to the west of Puu Waawaa. A conductance of 374 mhos would represent a zone one kilometer thick with a

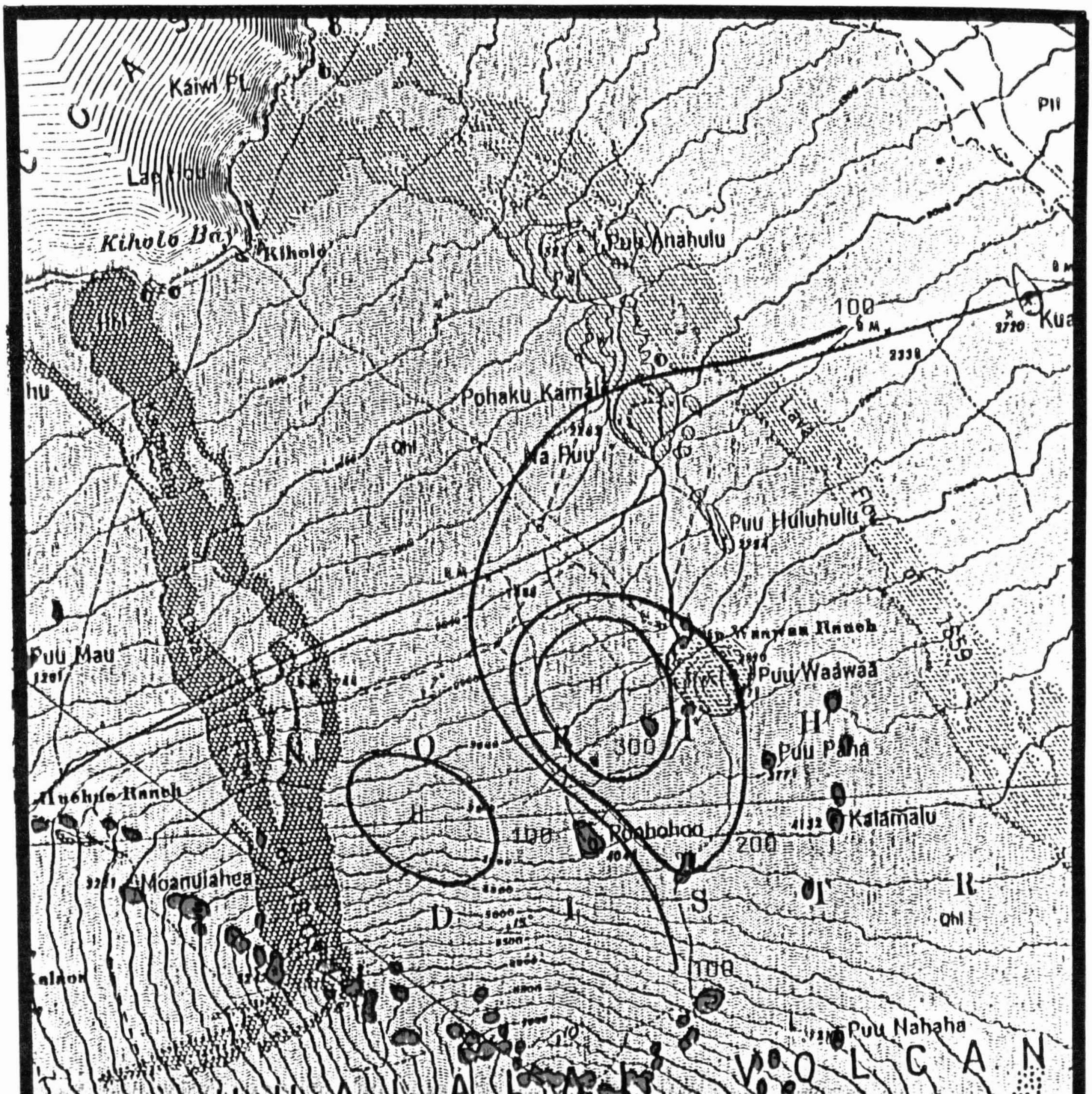


Figure 6. Contours of conductance, in mhos, as determined from the magnetotelluric survey, superimposed on the surface geologic map for the Puu Waawaa area.

resistivity of 2.7 ohm-meters, or a zone two kilometers thick with a resistivity of 5.4 ohm-meters. These are values low enough to be of interest in defining a geothermal system.

Coverage of Hualalai volcano is sparse, partiucarly in the area of the summit and the east-west trending rift structure. Further magnetotelluric sounding might indicate the presence of conductive rocks in this area as well.

Historical Seismicity.

The observation of seismic activity is often used to good effect in the search for geothermal systems. Areas of high heat flow and volcanic activity also are areas of high seismic activity. Some of this activity is tectonic in nature; that is, earthquake activity is associated with the faulting that takes place as crustal blocks move around. Other seismic activity is sometimes related directly to the intrusion of magma in an area of volcanic activity. Both types of activity are observed on Hawaii. Consistent earthquake activity is observed along the major faults that bound the individual volcanoes. Spasmodic or episodic activity is seen when volcanic activity is about to take place.

Because of the importance of knowledge of seismic activity in understanding and predicting the behavior of the volcanoes on Hawaii, a first-rate seismograph network has been maintained on the island for many years by the U. S. Geological Survey. The number of stations in this network varies from time to time, but ranges from a few dozen to forty or more. Most stations are located near the active zones of Kilauea Volcano, but adequate coverage is provided to map activity over the entire island. Stations near Hualalai include those at Kailua, Puu Waawaa, Waimea and Pohakuloa. The station density is adequate to assure that earthquakes with Richter magnitude 2 or larger can be located with an error of no more than about 2 kilometers in the Puu Waawaa area.

All earthquakes located in the Hualalai area during the period from 1963 until 1973 (the last year for which data are available) were used to compile a seismicity map of the Volcano. During this period, some 600 earthquakes of magnitude 2 or larger were located by the U. S. Geological Survey in the area covered by the map in Plate II. When epicenters are plotted on a map, they tend to show a moderately uniform distribution over the entire area, with a modest tendency to cluster about a few centers of activity. As a means for presenting the seismicity data in an informative manner, the following procedure was used. The area of Plate II was divided into regions one minute square. Then, the number of earthquakes in an area four minutes by four minutes was counted and plotted in the one minute square. The resulting contour map of seismcity shown in Plate II was obtained. Here, seismicity is expressed in terms of the probability that an earthquake of magnitude 2 or larger will occur in any given one minute square (roughly one mile square) in a century. It must be recognized that the probability of earthquake occurence is projected from a short base interval of one decade. Longer records of historical seismicity could provide a much different pattern of observed seismicity.

Two regions of markedly high seismicity are apparent on Plate II; one is located along the northwest face of Mauna Kea, while the other is located along an east-west trend passing near the village of Keauhou, and projecting inland towards the summit of Mauna Loa. Both of these elongate trends are almost certainly faults along which tectonic earthquakes take place consistently over time.

An anomaly of special interest is a bullseye of moderate activity in the vicinity of Puu Waawaa. This anomaly is circular in character, and so, is not so likely to be a major fault as the features described in the last paragraph. The level of activity -- 5 earthquakes per square mile per century -- is below the level of seismicity in the two elongate patterns, but there is a strong chance that earthquakes at this particular location are episodic, and so, they may have been undersampled in the decade from 1963 to 1973. The reason for this presumption is that in 1929, an intense swarm of earthquakes was observed to occur in the vicinity of the Puu Waawaa Ranch Headquarters. In a nine- months period from the fall of 1929 until the summer of 1930, some 6000 earthquakes were counted in the area. The largest were of magnitude 5 to 6. At the time, only a single seismograph was in operation at Kilauea summit, and during the swarm, a second was set up at Puu Waawaa Ranch, but no means was available for accurate epicenter location. It was thought at the time that the swarm of earthquakes was a precursor to an eruption of Puu Waawaa, but the activity finally subsided in 1930. There is a reasonable probability that the bullseye of activity at Puu Waawaa is the residual aftershock sequence from the 1929 swarm. The location of the area of activity is shown superimposed on a geologic map of Hualalai in Figure 7.

The east-west trending ridge of Hualalai which geomorphically is the most obvious feature of the volcano shows remarkably low seismic activity. It is among the most stable areas on the island of Hawaii.

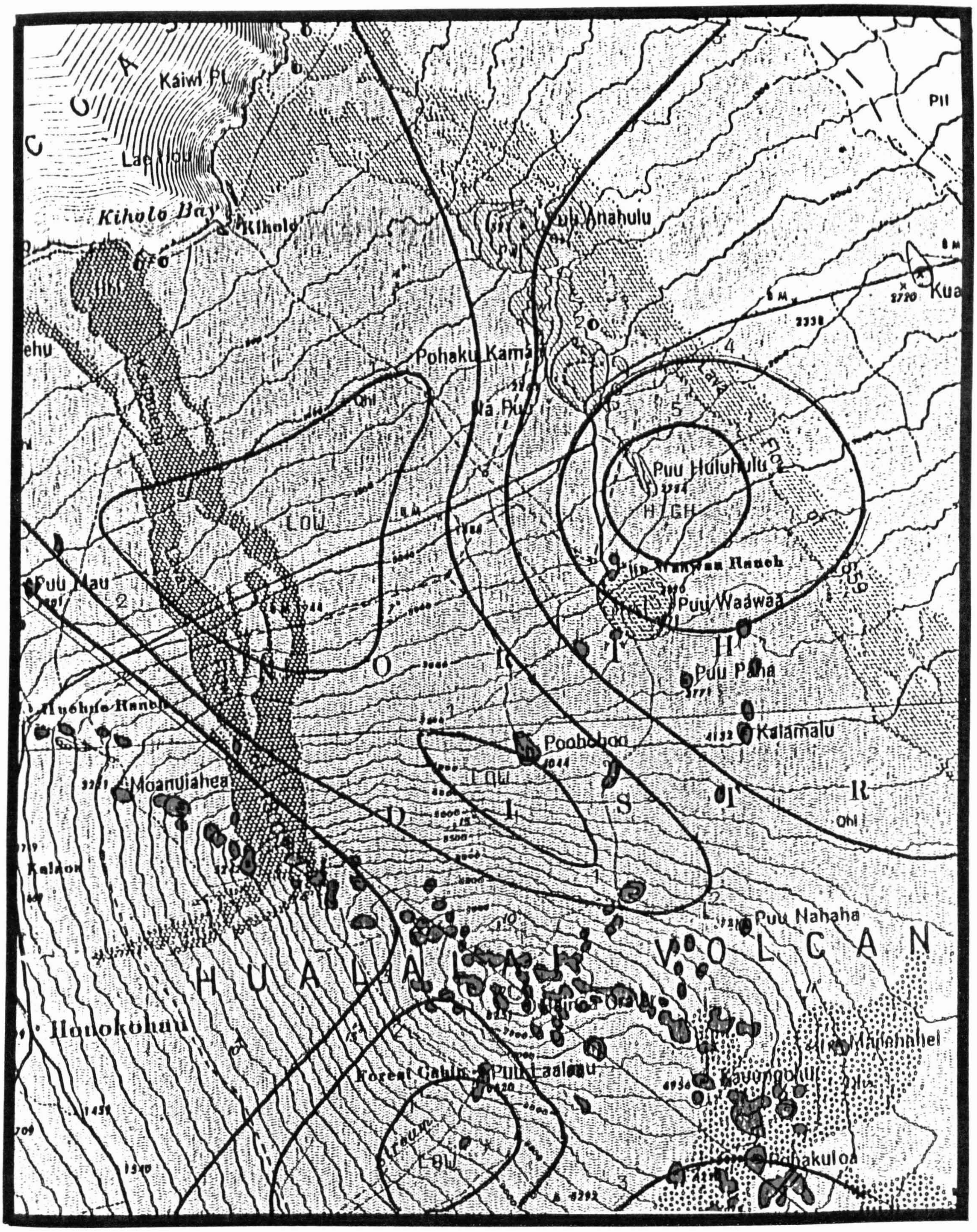


Figure 7. Summary of historic seismicity in the Puu Waawaa area.

Soil Mercury Content

The amount of mercury in soil has been found to be an excellent chemical indicator of thermal activity at depth. Mercury is an element that does not from strong bonds with other chemicals in rocks, and which can be liberated from rock structure at relatively low temperatures, such as those which are present in commercial geothermal reservoirs. The mercury in the subsurface is liberated by temperature and percolates to the surface where it escapes to the atmosphere. The rate of liberation is a function of mercury originally present in the rock, the temperature at depth, and the permeability to the surface. In areas of complex geologic structure, any one of these three factors can explain variations in soil mercury content. In Hawaii, where the rock type is uniform, variations in mercury content of the rock and in permeability to the surface are less likely to explain changes in soil mercury content than changes in temperature.

A soil mercury survey of Hualalai volcano was carried out by collecting samples at approximately 150 locations as indicated on Plate III. Samples were taken a few inches below the soil surface, with an attempt being made to exclude organic material from the samples. Organic materials make the analysis of the soil for mercury content difficult. The samples were sealed in small bottles and returned to the laboratory for analysis.

The samples were seived to obtain a half-gram portion consisting only of the fines for analysis. This sample was then heated to release the mercury content, with the vapors being passed through a gold thimble.

The thimble was then heated to liberate the mercury deposited on it, with the gas being passed through an atomic adsorption cell. The cell was calibrated against gas streams with known mercury contents to provide a readout in terms of the mercury content of the original sample. Reproducibility of measurement from the same source sample was within 20 percent. The threshold sensitivity of the equipment was a few parts per billion.

Normal soil mercury content in Hawaii in non-thermal areas is 20 to 40 parts per billion (ppb). The highest mercury content observed for any soil sample from Hawaii was one for a sample taken along the steaming crack of Kilauea Volcano above Opihikao in Puna, where a concetration of 8000 ppb was noted. A sample taken at the HGP-1 site, where temperatures of 600 F were found at 6000 feet depth exhibited a mercury concentration of 1000 ppb. Any mercury contents above a few hundred ppb are considered strongly anomalous in Hawaii.

Soil mercury contents observed on Hualalai volcano are all unusually high. The highest concentrtations exceed 1000 ppb, and these are noted in the vicinity of Puu Waawaa Ranch Headquarters. Concentrations above 300 ppb are seen for distances of several miles in all directions from the center

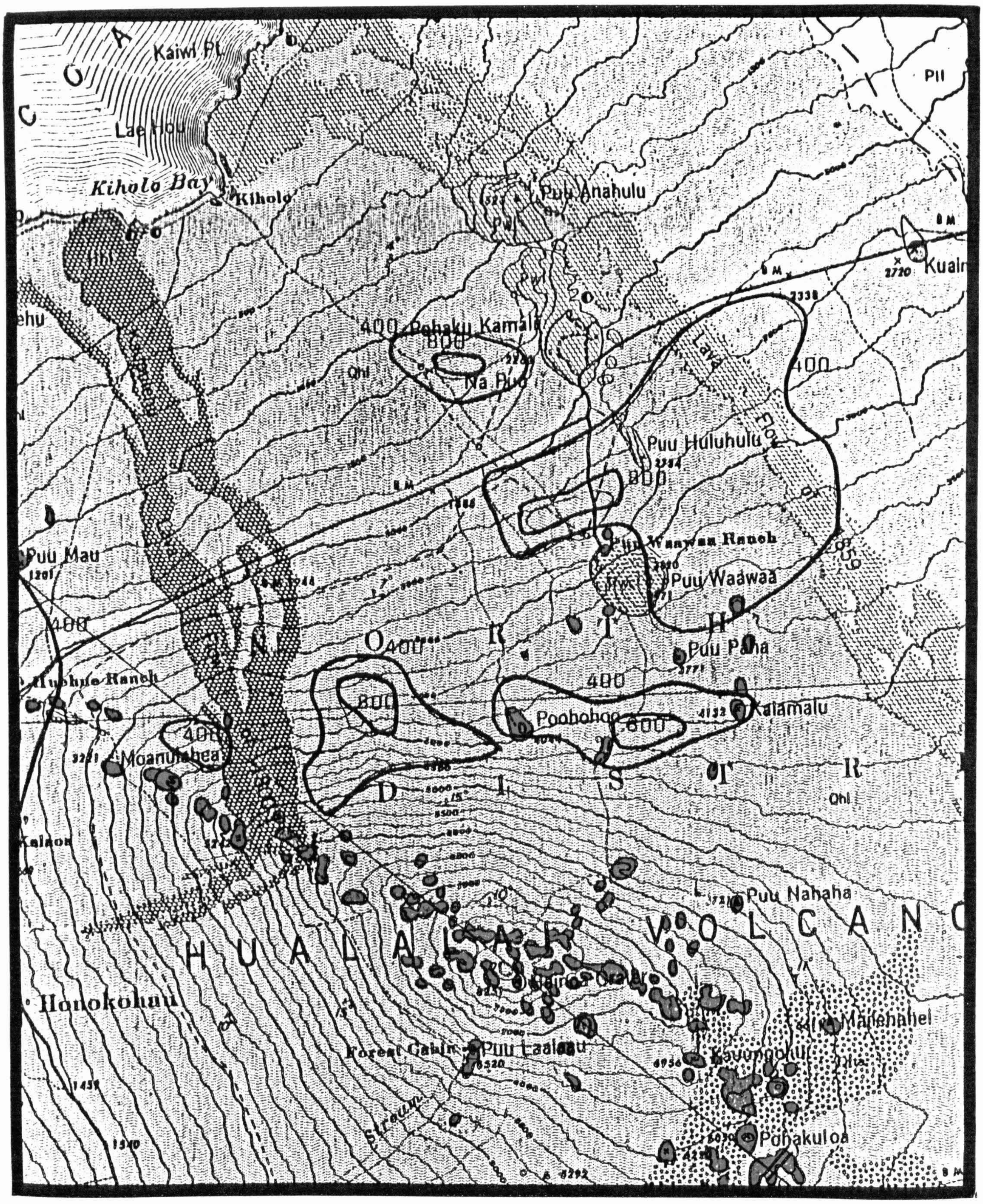


Figure 8. Mercury content in soil in the Puu Waawaa area. Contours are given in parts per billion (ppb).

of anomalous concnetration. It is not likely that the whole area is underlain by high temperatures, but rather that the large amount of mercury escaping to the surface in the center of the area migrates laterally once it reaches the surface. Traffic, wind, movement of animals, and similar factors will tend to spread out an area of high mercury conentration.

The areas of high mercury concentration are also shown superimposed on the geology of Hualalai volcano on Figure 8.

Resistivity Soundings

All of the surveys described so far have been of a reconnaisance nature, in that the details of subsurface structure cannot be determined from the field observations. A few measurements were made using the resistivity sounding method to investigate the probable depth to ground water in the vicinity of the Ranch Headquarters.

In resistivity sounding, an array of electrodes is expanded at a survey location to give information about the electrical properties of rocks at progressively greater depths. For the measurements to be described here, the Schlumberger array was used. In this array, four electrode contacts are made with the ground. The four contacts are located along a common line; the two outer contacts are used to provide current to the ground, while the two inner contacts, located halfway between the outer two, are used to measure voltage caused by current driven between the outer two. A series of measurements of apparent resistivity is made as the outer two electrodes are moved apart, providing deeper penetration of the current into the subsurface. The product of a survey is a resistivity sounding curve where values of apparent resistivity are plotted as a function of the electrode spacing (taken to be half the separation between current electrodes, by convention).

Initially, three resistivity soundings were carried out, with two of them being located at wells, one at the 1000-foot level on Puu Waawaa Ranch and the other at the

1000-foot level at Waikaloa Village, a few miles to the north. The third sounding was located in a flat area just north of the Puu Waawaa Headquarters. The location is shown on Plate I. The three sounding curves are shown on Figure 9.

The soundings made at the two well locations show a typical behavior for soundings made in Hawaii; the apparent resistivity remains high until spacings greater than the depth to sea level are reached. At larger spacings, the curves roll over to lower values of apparent resistivity as current penetrates to salt-water-saturated rock beneath the water table. A fresh water lens often floats on the salt water, depressing the salt water table below sea level. The amount of depression is about 40 feet for every foot of elevation of the fresh water table above sea level.

Sounding curves can be interpreted more precisely by computing models of hypothetical earth stuctures for comparison with field data. The two curves at well locations were interpreted to indicate the presence of a salt water table at a depth of 1173 feet below the surface at the Puu Waawaa well, and 1535 feet below the surface at Waikoloa. These would indicate a fresh water table riding about 4.3 feet above sea level in the first case, and 12 feet above sea level in the second case.

The sounding done at the Ranch Headquarters indicates a rollover to lower values of apparent resistivity at depths of a few hundred feet. This behavior is not appropriate for

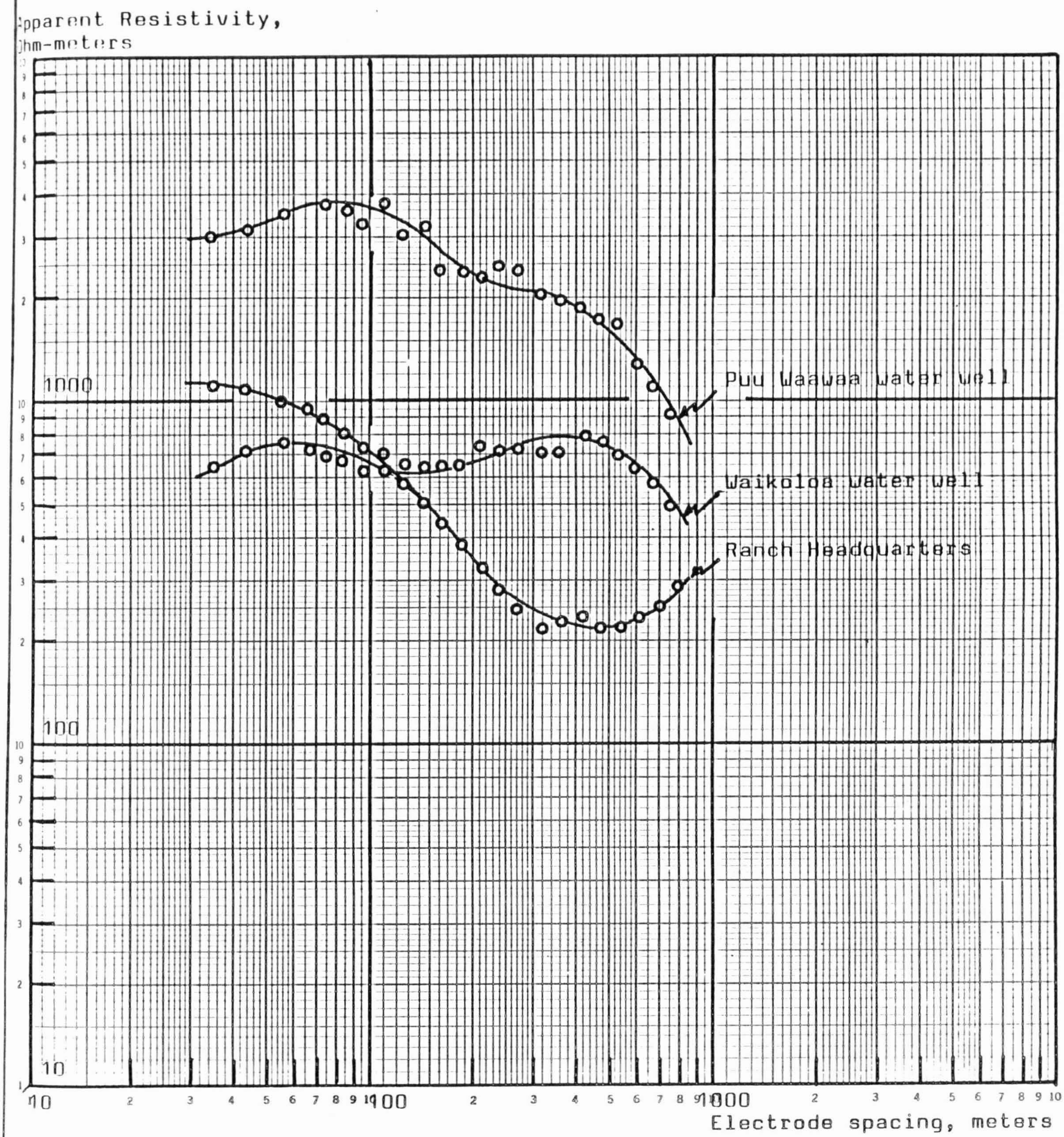


Figure 9. Schlumberger resistivity soundings from the Puu Waawaa area.

a location where the elevation is nearly 3000 feet. The data indicate the presence of significant amounts of water, probably brackish, starting at depths of 300 to 500 feet. This must represent perched water, as is often found in rift zones of Hawaiian volcanoes.

In view of the anomalously low resistivity observed near the Ranch Headquarters, a more extensive set of Schlumberger soundings was undertaken at the nine locations indicated on PlateI. The apparent resistivity curves obtained for these soundings are shown on Figure 10. Detailed interpretations were carried out on these data with results as follows. In the area around the Ranch Headquarters, unusually low resistivities were determined to be present starting at a depth of only a few hundred feet beneath the surface. The resistivities in this zone ar 200 to 400 ohm-meters. Such values are typical of water saturated basalt beneath sea level.

The zone of shallow, low resistivity values appears to extend from Puu Waawaa to the vicinity of Puu Anahulu. North of the Mamalahoa highway, the resistivity structure is more normal, with high resistivity (several thousand ohm-meters) extending at least to sea level.

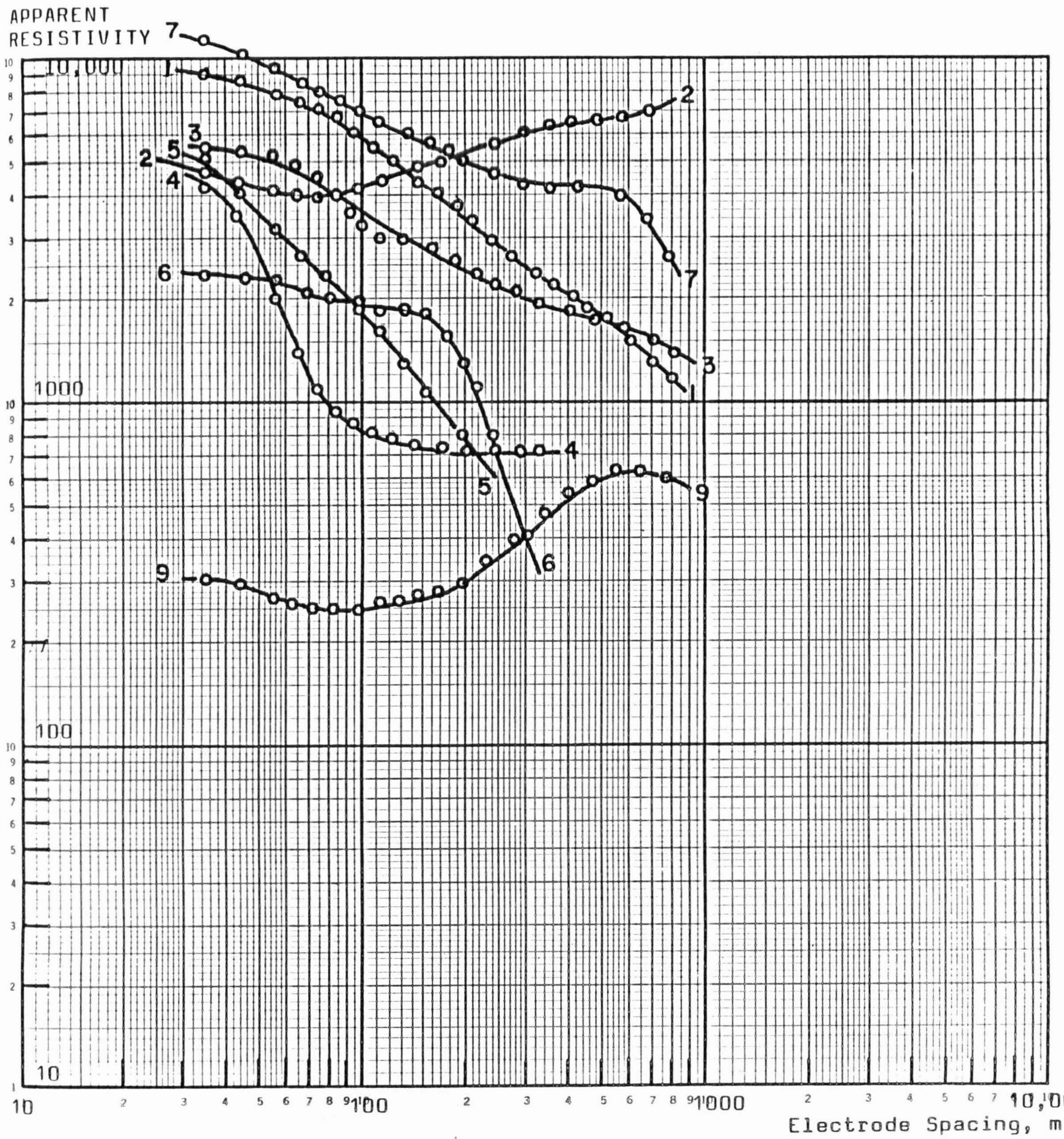


Figure 10. Additional Schlumberger resistivity soundings carried out in the Puu Waawaa area. Locations are shown on Plate I.

Self Potential Survey

The final stage in the preliminary evaluation of the Puu Waawaa geothermal prospect was a self potential survey carried out during March and April, 1978. The self potential method has proved to be highly effective in locating areas of magma intrusion on Kilauea Volcano, and was one of the primary sources of data used in locating the successful test hole at Puna.

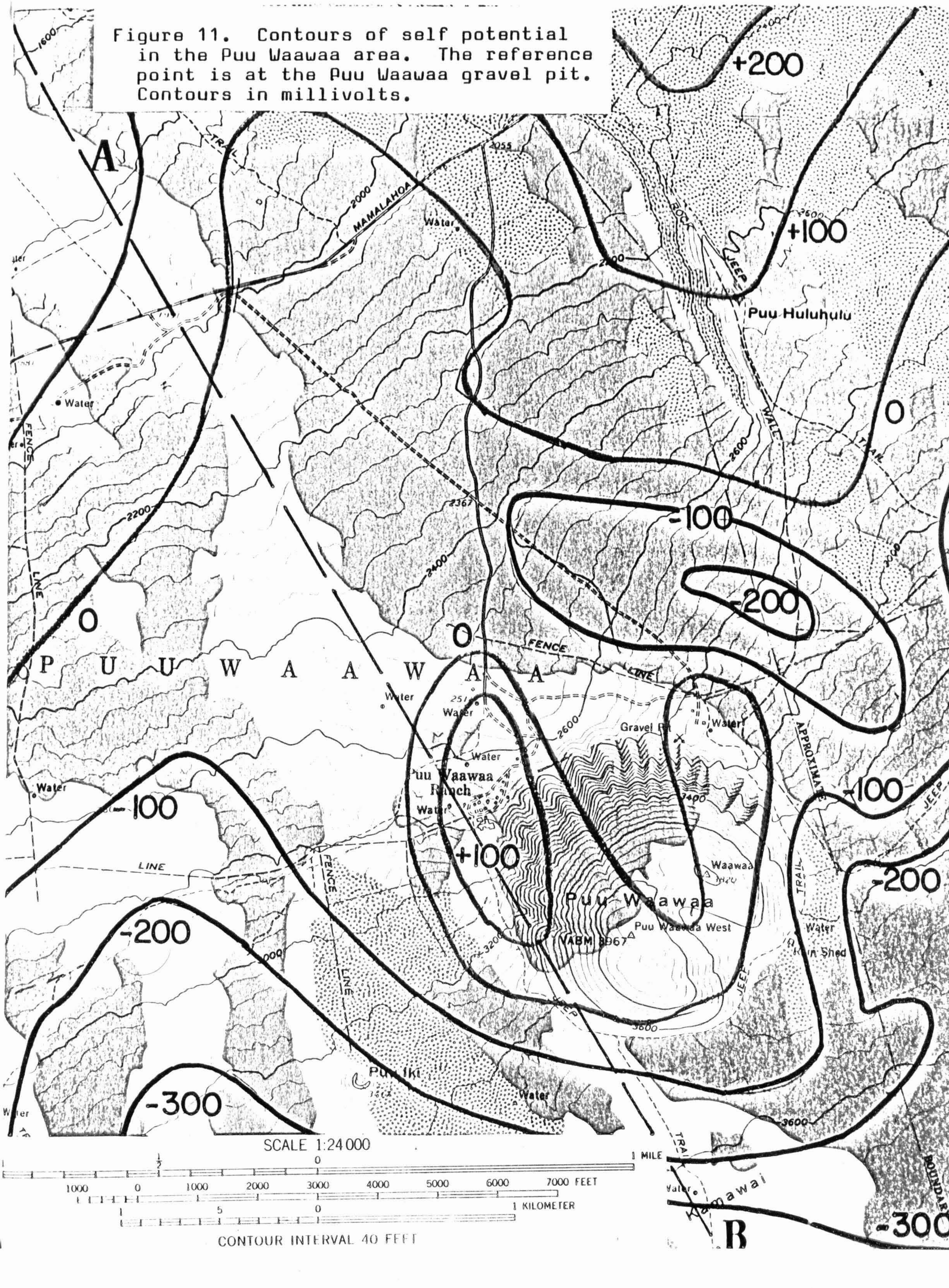
Self potential is the voltage that exists naturally between two points in the ground. Such natural potentials can have many causes, but in an environment such as that found on Hawaii, the principal source of natural potential is the movement of ground water through the basalt. When fresh water moves through unaltered basalt, a strong potential is generated, with the voltage being positive in the direction of water movement (downhill). The normal movement of groundwater to the ocean generates a self potential which amounts to about 100 millivolts per mile both in the Puna area, and in the Hualalai area. In areas underlain by hot intrusive masses, these self potential patterns are found to be strongly distorted, with anomalous self potentials ranging from a few hundred to several thousand millivolts being observed over known intrusive bodies on Kilauea Volcano. It is believed that convection of warm waters above the intrusives gives rise to these self potential features.

In the self potential survey done of the Puu Waawaa area, measurements were made using conventional non-polarizing electrodes for contact with the ground. The voltage between the contacts was measured with a four-decade digital voltmeter with a threshold sensitivity of 0.1 millivolt. Measurements were done using one electrode near the Puu Waawaa quarry as a reference point, and by extending a cable along the traverse to make measurements at intervals of one-quarter mile. Twenty-eight miles of intersection traverse were surveyed. A contour map of the self potential referenced to the quarry site is shown in Figure 11.

The normal behavior for self potential contours is to parallel the topographic contours, with the more positive values being downhill. It is clear that this behavior is strongly distorted in the immediate vicinity of Puu WaaWaa. This distortion can be seen on a profile of potential along a traverse oriented Northwest to Southeast , as shown in Figure 12. Here, the superposition of a positive self potential peak with an amplitude of 400 millivolts on a regional gradient of about 110 millivolts per mile can be seen clearly. The peak amplitude of the anomaly is approximately at the puu Waawaa ranch headquarters.

The depth to the source of a self potential anomaly can sometimes be estimated from the spatial extent of the feature. Considering the width of the anomaly shown in Figure 12, the self potential is being generated at a depth of about one-half mile, or approximately at sea level.

Figure 11. Contours of self potential in the Puu Waawaa area. The reference point is at the Puu Waawaa gravel pit. Contours in millivolts.



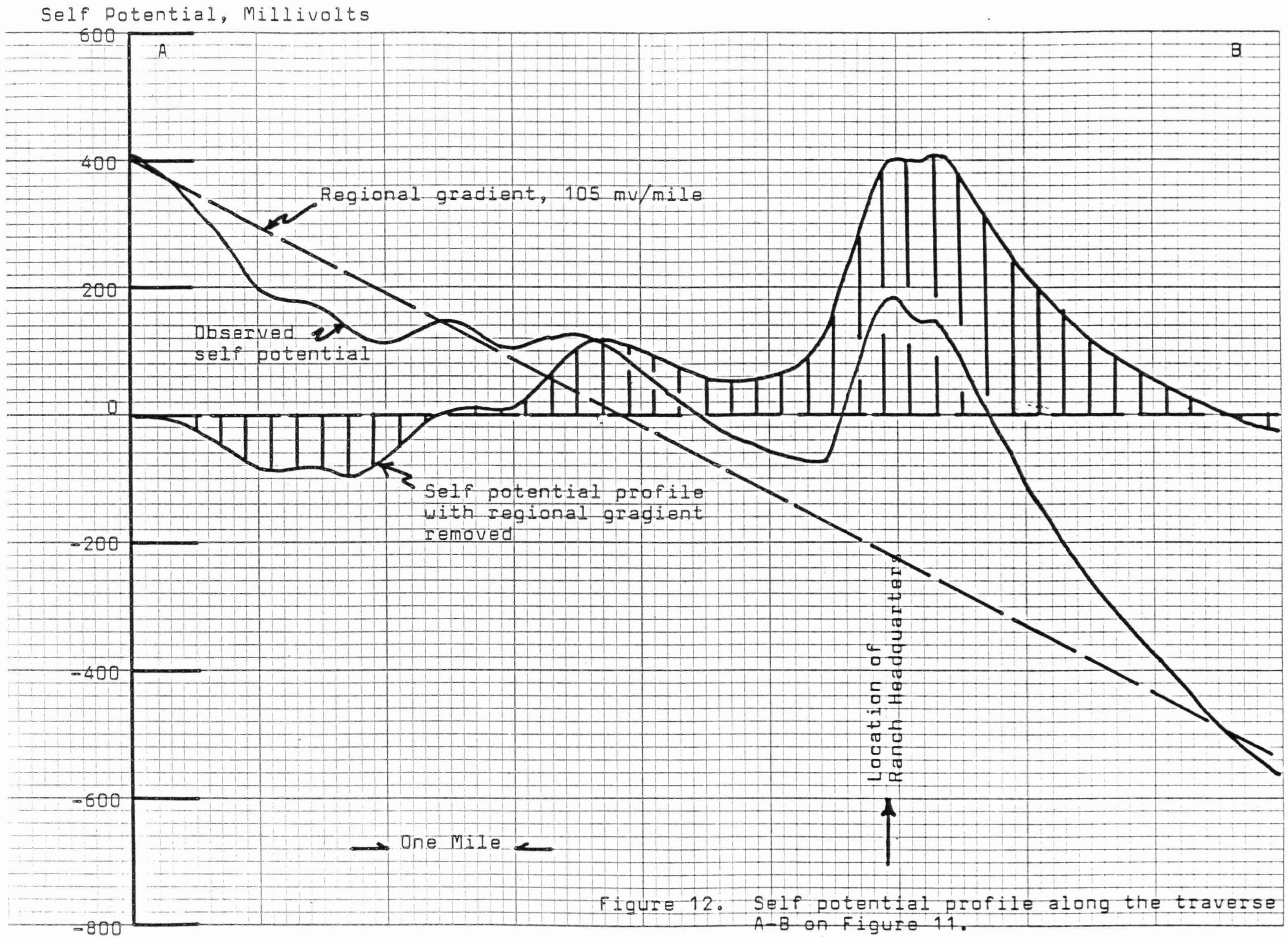


Figure 12. Self potential profile along the traverse A-B on Figure 11.

Summary

Various sets of data indicate a significant geothermal potential for the area around Puu Waawaa. The Puu Waawaa cone lies on the north-south rift of Hualalai volcano. It is characterized by a high level of mercury in soil. There is a local zone of high seismicity. Resistivity soundings indicate unusual high level water in the area. A positive self potential anomaly amounting to 400 millivolts is located at Puu Waawaa.

All of these factors have been observed at Kilauea and at Puna where geothermal test bores have been drilled. geothermal energy is present. A definitive test would consist of drilling one or two boreholes to determine whether or not unusually high temperatures are present. The first priority location for such a test is at the ranch headquarters, while a second test could be drilled near Puu Anahulu. The depth of the test wells should be about 1000 feet below sea level. Further work is warranted to determine if commercially producible geothermal energy is present.

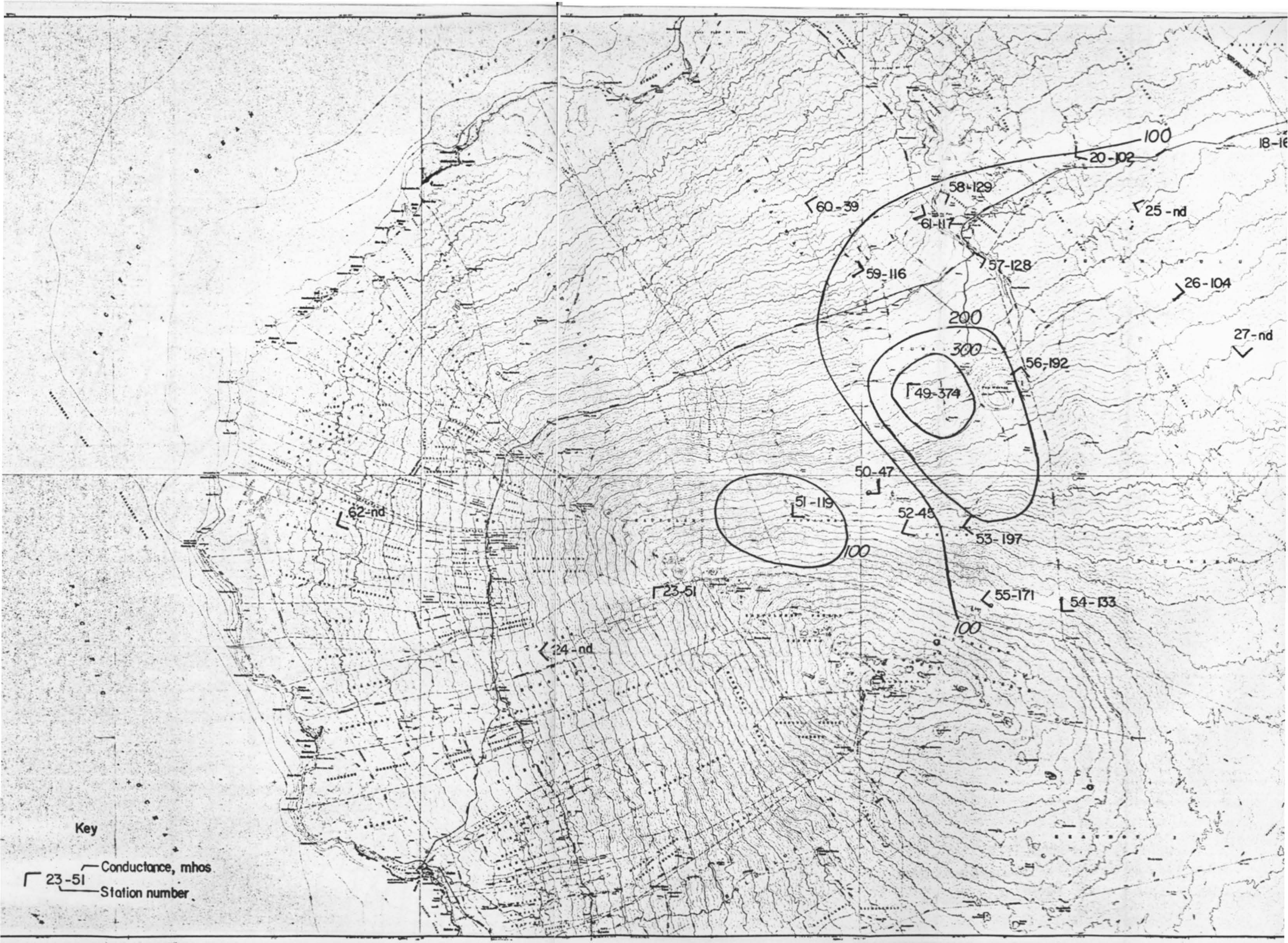


PLATE I. APPARENT CONDUCTANCE FROM MAGNETOTELLURIC SURVEY OF HUALALAI VOLCANO

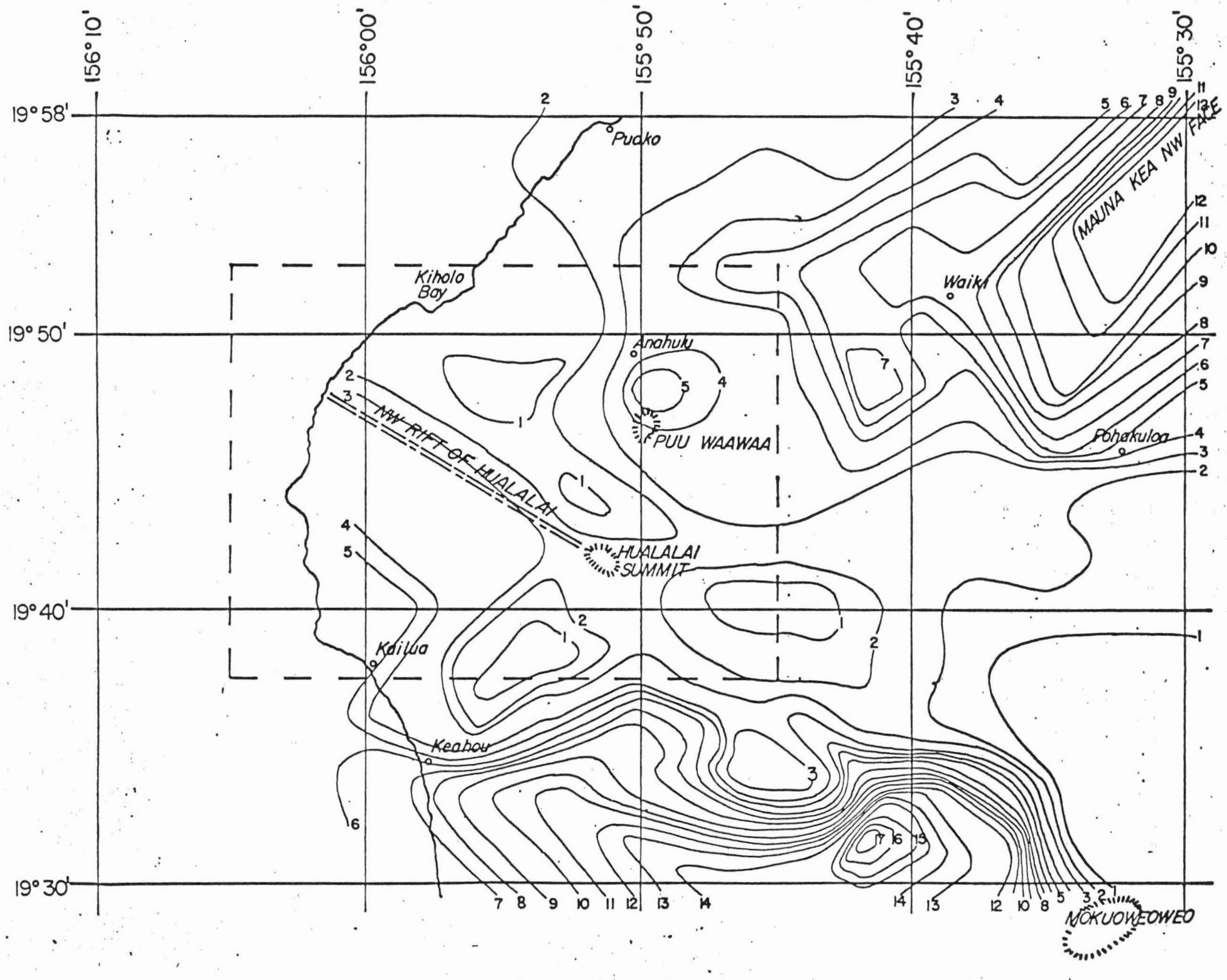


PLATE II. SEISMICITY OF HUALALAI VOLCANO

REFERENCE: PUUWAAWAA GEOTHERMAL PROSPECT

Preliminary Plan for Exploration and Development

A geothermal lease agreement is held by Geothermal Exploration & Development Corp. (GEDCO) and assigned to the Partnership, for a total of approximately 687 acres, together with an assignment of Occupier's rights for approximately 105,000 acres, in possession of Mr. Bohnett by virtue of a General Lease from the State of Hawaii, expiring in the year 2000.

Based upon geophysical evaluations by Dr. George V. Keller, one or more deep exploratory water wells will be drilled in 1978 on Fee Simple land owned by F. Newell Bohnett on which mineral rights have not been reserved by the State of Hawaii. These wells will be carefully checked for chemical analysis and temperature gradients.

Exploration and Development would be performed by Puuwaawaa Steam Co. (STEAMCO), a limited partnership, with GEDCO as General Partner and Operator and F. Newell Bohnett as Limited Partner. Initial temperature wells will be drilled on the Fee Simple property. In order for this prospect to be regarded as a viable commercial geothermal venture, it will be necessary to expand the useable acreage. To accomplish this STEAMCO will make application to the State for mineral (geothermal rights) on 5,000 adjacent acres of land.

If the (Phase I) exploratory water wells indicates higher than normal temperatures and there are other geothermal indicators, then a site will be selected for one wildcat exploration well, and drilling permit will be applied for and drilling will take place (Phase II), in 1979. Testing of the well will determine the next course of action,

a) Continuation by drilling step out wells,
b) relocation to another exploratory site,
c) abandonment of the project.

Assuming a commercial quantity of geothermal steam is discovered, then a development program (Phase III) will be launched, and the balance of the required geothermal wells will be drilled to meet the HELCO's needs. Meanwhile long term testing will be continued on the completed well, using silencer and scrubbing techniques to reduce the nuisance factors as far as possible.

The relative isolation of this area should help to keep the nuisance problem to a minimum. The drilling program will be scheduled so as to try and complete all drilling and most of the long term testing by the end of 1980 or early 1981 in sufficient time to demonstrate to HELCO, that a reliable source of geothermal energy is available so to permit design and construction by 1982. To realize the earliest market opportunity development of steam for geothermal power plants would be planned in increments of 10 megawatt each.

During the interim period, after well field completion 1980, and until plant production approximately 1983, continued testing and monitoring will take place, and well head equipment will be kept serviced and operable and ready to tie into transmission lines to the power plant. The installation and maintenance of these transmission lines will be included at the time plant design and construction plans are made and are not provided for under this present concept.

All geophysical work and evaluation would be conducted by, or under the supervision of Dr. George V. Keller. Outside consultants, qualified and experienced in reservoir evaluation of long term testing would be retained as needed. Drilling programs would be drawn up and conducted by the Craddick Brothers.

Equipment, owned by principals of GEDCO, is available in the islands and tooled up to handle all depths within the range of this program.

Hilo Electric Light Company (HELCO) and its parent company, Hawaiian Electric Company (HELCO), have given assurances that the next power plant in West Hawaii would be constructed to use geothermal power if it could be produced economically and proven up in sufficient time. See Exhibit "C".

It is our intent to be competitive with oil prices, which are presently projected to be in the range of $4.00 per million BTU's or $24.00 per barrel of low sulphur oil by 1982. Therefore, we have selected $.03 per killowatt hour as a reasonable price goal to aim for, and revenue projection is based on this assumption. It is also assumed that 4 wells plus one standby (5 megawatt each) will be sufficient to power two (2) 10 megawatt plants. This may have to be revised after well testing is completed. A contingency is carried in the cost estimate for one (1) common injection well, which may be expected to become available as an unsuccessful steam well, (using a success ratio of 1:5). Both the standby well and the injection well would be commonly used by both 10 megawatt plants.

Although the domestic power needs for the island of Hawaii are projected to grow at approximately 5 megawatts per year, we are restricting this present concept to providing geothermal steam for the first 20 megawatts required for HELCO plants in West Hawaii.

ENVIRONMENTAL ASSESSMENT AND LAND USE

Drilling will be continuous 24 hours per day, seven days per week. The drill rig will have a 100 ft. tower and have its own electricity generating equipment. There will be a crew of approximately 20 , most of them coming from local hire.

Plans, procedures and operations will be in accordance with the State's Rules and Regulations governing geothermal drilling.

Regarding the guidelines established in the Land Use Regulations of the Land Use Commission, it is submitted that the requested use is a reasonable one even though unusual for agriculturally classified land. In addition, it is the kind of use that should be permitted as a special use in the more general and overriding public interest, and as not in any substantial way at variance with the general purposes for which Hawaiian land classifications are established, in that:

(a) The use requested is in furtherance and in keeping with needs and objectives of public interest and is within the needs and objectives of the Land Use Law and Regulations and the public interest of the State of Hawaii. Energy requirements are the single most unsolved element in the economic well-being equation for the County and State of Hawaii. Dependence on imported energy stands to limit the potential well-being and economic growth of the County and State. The use requested is to the purpose of determining the quality and extent of geothermal resources available to serve needs from indigenous energy sources. Geophysical and geological studies indicate that geothermal resources may be present in the area, but final proof will rely on drilling and testing a deep well.

(b) The use requested will probably produce a net beneficial effect to the surrounding property with minimal, if any, adverse effect on surrounding property. The operations necessary to the use will be strictly confined to an area of about one acre per well. It is predicted that a net product of useful irrigation water can result at minimum, as one beneficial effect of the proposed use.

(c) Public agencies will not be required to provide or relocate roads, streets, schools, sewers, water, drainage, or additional police and fire protection as a result of the use requested.

(d) District boundaries and regulations were established prior to the realization that geothermal resources were likely to be present and certainly before particular locations of these resources were known. The use requested is in furtherance of an attempt to know more about the existence and extent of geothermal resources in Hawaii so as to apprise land owners and appropriate public authorities of their potential for beneficial use within the State of Hawaii.

Only in the past five to six years have the dual facts of an energy crisis and the potential availability of geothermal energy been within the category of general information. It is natural, therefore, that the requested use should not have previously appeared as one of the officially recognized uses of land in this classification.

(e) From all appearances and contact with present uses of the land proposed for the requested use, present operating would not be hindered. It is possible however that the water by-product of the development of geothermal energy will make possible more extensive agricultural use of the land nominated and surrounding land for the near and long-term future.

The area of the requested use is generally characterized as rocky, and covered by grass underlain by old lava flows.

(f) The requested use will not preclude future agricultural use of the land. Even full-scale development of geothermal energy would occupy and alter no more than ten percent (10%) of the total surface area of the land. The balance of the land within this area would be allowed to remain as it now is and would be suitable for the present uses designated in the land use laws and regulations, at least to the extent it is now useful for these purposes.

It is the nature of geothermal development, in the active fields worldwide, particularly that agricultural operations can continue in about the same form as they did, or would have, were geothermal resources not being taken from the area. If anything is changed, it is usually to initiate an improvement over previous possibilities in the same area.

(g) The public welfare will be benefited in all respects by the use proposed and, considering the general public interest, is the highest and best use of the land nominated in this special use application. By proving and producing this form of energy, in this location where where underwater tansmission cable technology can bring power to a domestic power market which is rapidly expanding, a large step toward energy independence for Hawaii will be taken. Geothermal energy is probably the most efficient and least disturbing form of energy available in the general geographic area of this application.

The district can benefit in many ways from the proposed use. At present, the lack of water and power is important to the best use of resources and manpower in this area. The prospective higher costs of energy tend to exacerbate the situation.

(h) In addition to a physical survey to determine the exact geographical location of the proposed drilling sites, the immediate area has been surveyed to discover the presence of historical sites and evidence of the habitat of an endangered species. Such evidence as has been adduced by this survey does not indicate a condition on the property nominated that would be harmed or altered to the detriment of any specie.

With reference to the Hawaii County General Plan, it appears that the policy of the County regarding development of power for use by the consumers of the County of Hawaii and with respect to economic developments are in harmony with the proposed project. The proposed project is of an investigatory nature which can lead to the type of large development referred to on page 10 of the General Plan, but is not now at a stage of certainty, in terms of magnitude, that would permit a prediction of kinds of social, economic, and physical impact that are referred to at that point in the plan.

Discovery of a geothermal source on the Kona side of Hawaii would also work to the ultimate economic benefit of users of electricity on Hawaii, by centralizing the source in the area of greatest immediate growth needs, making plant construction and distribution much more feasible and economical for the utility - (see attached letter dated April 7, 1978 from HELCO - Exhibit "C").

July 10, 1978

Reference: Puuwaawaa Steam Co. (STEAMCO)
Application for Geothermal Mining Lease 182.5

Certification of Qualifications

We hereby certify that Geothermal Exploration & Development Corp. (GEDCO) being the General Partner of the applicant partnership, STEAMCO, is experienced and qualified to undertake the work outlined in the preliminary plan.

We further certify that the acreage applied for does not exceed the permissable limits as per Rule 3.10 of the Rules and Regulations governing geothermal leases.

The authorized signators of the partnership are F. Newell Bohnett, Limited Partner together with any one of the following officer of GEDCO, the General Partner.

E. C. Craddick, Presigent	- GEDCO
D. O. Craddick, Vice President	- GEDCO
W. R. Craddick, Vice President	- GEDCO
Martin Anderson, Vice President	- GEDCO

Copy of the partnership recorded with the Department of Regulatory Agencies is attached.

GEOTHERMAL EXPLORATION &
DEVELOPMENT CORP.
(General Partner)

BY E. C. Craddick
E. C. Craddick, President

F. NEWELL BOHNETT
(Limited Partner)

F. Newell Bohnett

ECC/sm

Filing Fee: $.75 per partner

STATE OF HAWAII
DEPARTMENT OF REGULATORY AGENCIES
Business Registration Division
1010 Richards Street
Mailing Address: P.O. Box 40, Honolulu, Hawaii 96810

In the Matter of the
Limited Partnership

of

PUUWAAWAA STEAM CO.

CERTIFICATE OF LIMITED PARTNERSHIP

The undersigned, being desirous of forming a limited partnership, hereby certify, in accordance with the provisions of Chapter 425, Part II, Hawaii Revised Statutes, as follows:

I. The name of the limited partnership shall be PUUWAAWAA STEAM CO.

II. The character of the business of the partnership shall be to explore, develop, and market geothermal power.

III. The principal place of business of the partnership shall be C/o Geothermal Exploration & Development Corp., 2828 Paa Street, Suite 2085, Honolulu, Hawaii 96819.

IV. The names and residences of the partners are as follows:

GENERAL PARTNERS	ADDRESS
Geothermal Exploration & Development Corp.	2828 Paa Street, Suite 2085 Honolulu, Hawaii 96819

LIMITED PARTNERS	ADDRESS
F. Newell Bohnett	44-600 Kaneohe Bay Drive Kaneohe, Oahu, Hawaii 96744

V. The term for which the partnership is to exist is from the date of filing of this certificate in the Department of Regulatory Agencies and shall continue until dissolved or terminated.

VI. The amount of cash contributed by each of the limited partners is as follows:

LIMITED PARTNERS		CASH CONTRIBUTION
F. Newell Bohnett	June 16, 1978	$300,000.00 Cash
	Additional later if required	$100,000.00 Cash.

No other property has been contributed by the limited partners.

VII. No additional contributions have been agreed to be made by the limited partners. (See Above).

VIII. The time when the contributions of the limited partners are to be returned shall be at the dissolution or termination of the partnership.

IX. The share of the profits which the limited partners shall receive shall be the pro-rata share based on the amounts of their contribution as such amounts bear to the total amount contributed herein by both the general and limited partners.

Limited Partner - F. Newell Bohnett - 2/3

General Partner - Geothermal Exploration & Development Corp. - 1/3

X. A limited partner shall have the right to substitute an assignee as a contributor in his place with the consent of a general partner.

XI. On the death, retirement or insanity of a general partner, the remaining general partner or general partners, if there then be any, shall have the right to continue the business.

XII. There is no right of a limited partner to demand and receive property other than cash in return for his contribution.

IN WITNESS WHEREOF, the undersigned have caused this Certificate to be executed this 5th day of June, 19 78.

LIMITED PARTNER:

F. Newell Bohnett

GENERAL PARTNER:

Geothermal Exploration & Development Corp.

By: E. C. Craddick, President

INDIVIDUAL ACKNOWLEDGEMENT

STATE OF HAWAII) ss.
County of Honolulu)

On this 23 rd day of June, 19 78, before me personally appeared F. NEWELL BOHNETT ---

to me known to be the person (s) described in and who executed the foregoing instrument, and acknowledged that he executed the same as his free act and deed.

Annette L. Pipi

Notary Public, First Judicial Circuit, State of Hawaii

My commission expires Nov. 29, 1978

P-182 (REV 7-62)

Corporate

STATE OF HAWAII)
CITY & COUNTY OF HONOLULU) SS:
)

On this 19th day of JUNE, 1978, before me appeared E. C. CRADDICK to me personally known, who, being by me duly sworn, did say that HE IS THE PRESIDENT of GEOTHERMAL EXPLORATION & DEVELOPMENT CORP, and that the seal affixed to the foregoing instrument is the corporate seal of said corporation and that said instrument was signed and sealed in behalf of said corporation by authority of its Board of Directors, and the said E. C. CRADDICK, PRES. acknowledged said instrument to be the free act and deed of said corporation.

J. Dickie

Notary Public, 1st Judicial Circuit
State of Hawaii
My Commission Expires: 3-26-81

REFERENCE: PUUWAAWAA PROSPECT

Supporting Narrative - For approval of negotiating mining lease with applicant under HRS 182.5 without public bidding.

Geothermal Exploration and Development Corp. (GEDCO) has entered into a partnership agreement with Mr. F. Newell Bohnett for the exploration and development of geothermal energy on his fee simple property located at Puuwaawaa and Puuanahulu in West Hawaii together with an assignment of occupier's rights on leased land. The fee simple represents two parcels of land approximately 32 acres and 650 acres respectively, being approximately 2 miles apart.

The land adjoining and surrounding the fee simple parcels is occupied by F. Newell Bohnett under a General Lease from the State expiring in the year 2000, and is used for cattle ranching. Because of the economic and social importance of finding and developing alternate sources of energy in Hawaii, it has been recognized by the occupier that the highest and best use of the fee simple property as well as the adjoining lease land would be for geothermal development providing exploration proves successful.

However, in order to induce either a lender or a joint venture partner to participate in such a risk, it is necessary that the development concept include a sufficiently large area of land to form a viable prospect. It is our considered opinion that a total working prospect of 5,000 acres would be necessary in order to allow orderly exploration and development so that sufficent sites can be selected within limits of environmental restriction and geophysical findings. It is also necessary that sufficient acreage be included to allow for future expansion of the geothermal field. The development concept is for an initial 20 megawatts of power by 1983, however, the predicted growth rate of 5% annually indicates an ultimate need for West Hawaii by the year 2000 of approximately 100 megawatts.

The owner and occupier, Mr. F. Newell Bohnett, in recognition of the potential importance of the discovery of geothermal power in West Hawaii will be exposed to the inconveniences and nuisances related thereto. This can be mitigated to the extent that adjoining lease land is made available by the State for inclusion in the prospect area, by permitting a wider selection of alternate drilling and plant sites so as to have the least environmental impact on the ranch living area.

The fee simple land of approximately 687 acres would be pooled together with the 5,000 acres of lease land to make up the total geothermal reserve. A specific area within the pooled area will be unitized for optimum development of the indicated geothermal reservoir. Within this unitized area, selections of drilling and plant sites will be made by the best combination of economic, geophysical and environmental considerations. The remaining acreage will be retained as a buffer zone. These sites will be subject to the approval of the County Planning Commission and the State Land Use Commission.

As a first step, one deep temperature well will be drilled on the ranch house property in June/July 1978 to corroborate the geophysical studies which have already been done in the area.

Positive results will then require further temperature well probes, or lead directly to the nomination of specific locations for deep exploratory efforts. This would of necessity involve the lease area adjoining the fee simple acreage as part of a related effort in evaluating the location and extent of a potential geothermal reservoir.

We submit that this application should receive favorable consideration for the following reasons:

1. GEDCO has spent considerable time and effort over the past two years in locating an area of geothermal potential on the west side of Hawaii where the most rapid domestic growth for electric power exists, and where HELCO has stressed their future needs (see attached letter from HELCO dated April 7, 1978).

2. The owner and occupier of the fee simple land and leased land has demonstrated his willingness and cooperation in making this prospect available for exploration and development within tolerable environmental limits, and has gone a step further by participating in funding and assuming a working interest in the total prospect as a limited partner with GEDCO.

3. The viability of this as a geothermal prospect necessitates control over a large enough parcel to provide for working freedom and selection of plant and drill sites commensurate with environmental and geophysical considerations, and to provide reasonable protection against exploitation of a costly pioneering effort.

4. The lease land is presently in the custody and control of the occupier, Mr. F. Newell Bohnett, and any variance of use, or any work performed thereon such as would in any way interfere with the prevailing life style and useage must be recognized as directly affecting the occupier, who must therefore be regarded as a party of special interest in the matter of geothermal development in the Puuwaawaa area.

5. The earliest possible development of the West Hawaii geothermal potential would be represented by the Puuwaawaa prospect because of the geophysical work already completed and because of the position of readiness to proceed with actual drilling operations. Considering the requirements of the geothermal rules and regulations it is estimated that a significant time saving would be realized if the lease is negotiated with the occupier rather than bid publicly.

The partners (GEDCO and F. Newell Bohnett) have a development plan now ready to put in effect with drilling equipment at the site, and a long term funding program is moving forward under the Geothermal Loan Guaranty Program (GLGP).

6. The (GLGP) federal funding assistance program, especially designed for the development of a prospect of this nature, is available and can be utilized providing the partnership meets all criteria, one of which would be a sufficiently large acreage to represent a viable long term prospect with a resultant greater chance of success and repayment of the federally guaranteed loan. This would represent the first GLGP opportunity of participation by a Hawaiian owned and operated small business concern.

7. The principals of GEDCO have had a pioneering position in geothermal promotion as an alternate energy source, since its inception approximately 5 years ago and have local expertise derived from over 20 years of drilling in the islands, and are ready to move ahead rapidly with a definitive program of action.

8. GEDCO has always maintained a policy of cooperation with the geothermal interest of the State of Hawaii in meeting objectives for long range energy planning, and would expect to continue this policy for the Puuwaawaa prospect.

9. The Rules and Regulations governing geothermal are now adopted and ready, together with a precedent geothermal lease agreement between the State and an Occupier. The foregoing would provide readily available guidelines for processing a lease agreement with GEDCO for the Puuwaawaa lands.

10. Finally, assuming that early geothermal development is an important objective of the State of Hawaii, and that an early determination of this potential is necessary for long range planning of the State economy, and for meeting early opportunity presented by industry (such as indicated by the manganese nodule industry), then the position of experience and readiness presented by GEDCO should have merit, and a negotiation of a geothermal lease as applied for under HRS 182.5 should clearly work in the best interests of the State of Hawaii.

RECORDATION REQUESTED BY:

AFTER RECORDATION, RETURN TO:

RETURN BY: MAIL ( ) PICKUP ( )

ASSIGNMENT OF OCCUPIER RIGHTS

KNOW ALL MEN BY THESE PRESENTS:

That F. NEWELL BOHNETT, owner of Puuwaawaa Ranch Limited located in the County of Hawaii, State of Hawaii, hereinafter referred to as the "Assignor", for and in consideration of the sum of TEN AND NO/100 DOLLARS ($10.00) paid by PUUWAAWAA STEAM COMPANY, whose business and post office address is Suite 2085, 2828 Paa Street, City and County of Honolulu, State of Hawaii, hereinafter referred to as "Assignee", receipt of which is hereby acknowledged, hereby assigns, transfers, and sets over unto the said Assignee certain rights and benefits set forth in Chapter 182 of the Hawaii Revised Statutes pertaining to rights and benefits of occupiers of land in which the State of Hawaii claims an interest in geothermal resources by reservation of mineral rights in grants or patents. This assignment includes all said benefits and rights to the subsurface of the lands described herein, and Assignor will execute all documents and do all other acts reasonably necessary to place Assignee in his stead in all particulars pertaining thereto.

The rights and benefits assigned herein pertain and are appurtenant to the following described parcels of land (hereinafter referred to as "the land"), located in Hawaii, more particularly covered under Tax May Key 7-1-01 through 7-01-04 (excluding 7-1-01, parcel 2).

This Assignment of rights and benefits shall be subject to all applicable laws, ordinances, rules and regulations of the Federal, State and County governments, the terms and conditions of a geothermal lease to be issued by the State of Hawaii to Assignee, and the terms and conditions hereof.

Assignor and Assignee mutually agree as follows:

1. Assignee shall pay whatever royalties may be due to the proper parties indicated by legal agreement, consistent with established business practice for the industry.

2. Assignee shall have the right and option to use surface areas of the land necessary or convenient to the production of geothermal resources by Assignee, subject to the following terms and conditions:

(a) Surface areas to be used and the uses thereof shall be subject to the approval of Assignor, which approval shall not be arbitrarily or unreasonably withheld.

(b) The use of such surface areas shall be subject to existing leases and uses by Assignor's tenants, and Assignee at its expense shall negotiate with such tenants for use and possession of such surface areas. At its sole expense, Assignee shall pay for all damages to the tenants' crops, relocation costs, if any, and other items of damages claimed by the tenants and approved by Assignee. If Assignee is unable to reach agreements with Assignor's tenants, then Assignee will locate such surface uses on other areas of the land not leased or used by tenants.

(c) Assignee at its option shall lease from Assignor the surface areas to be used by it for six months duration or more as follows:

(1) For any contemplated temporary surface use of the land of six months duration or more, the terms of the lease or leases therefor shall be established by mutual agreement according to the length of the use of uses contemplated by Assignee. The term of any long-term lease hereunder shall be for a term co-terminous with the term of the geothermal lease to be issued by the State of Hawaii in the case of surface uses permanently required for wells completed to production, pipelines for production and disposal, electrical generating plant or plants, and transmission line towers.

(2) The lease rentals payable to Assignor hereunder for each area leased shall be five percent (5%) of the fair market value of the land area based on the use proposed by Assignee, exclusive of improvements thereon erected by Assignee and unencumbered by any lease, as established by mutual agreement of Assignor

and Assignee prior to the commencement of the term of the lease for the first five (5) year period thereof. The lease rentals for each successive five (5) year period thereof based on fair market value as aforesaid shall be determined by mutual agreement of the parties prior to 90 days before the expiration of the five (5) year fixed rental period then in effect, provided that the annual rental payable for each such period shall not be less than the annual rental for the period next preceding. In the event the parties are unable to reach an agreement respecting said fair market value not less than ninety (90) days prior to the termination of each lease period, the fair market value, based on the use of the leased area, exclusive of improvements thereon erected by Assignee and unencumbered by any lease shall be determined by appraisal as hereinafter provided, provided further that if and whenever the fixing of such rental is delayed pending an appraisal, the Assignee shall continue to pay the same rental which has been paid during the last preceeding rental period and shall promptly pay the deficiency, if any, upon conclusion of the appraisal proceeding.

(3) Assignee will not be required to purchase or lease roadways and no compensation will be paid to Assignor for the use of such

roadways, provided that Assignee shall pay all real property taxes allocable to roadways used exclusively or primarily by Assignee in its operations. As to other roadways used in common by Assignee and Assignor and its tenants, Assignee shall pay a reasonable share of the real property taxes as allocated by Assignor. All roadways used by Assignee shall be maintained by Assignee and Assignor and its tenants shall have no expenses or liabilities in connection therewith, unless otherwise mutually agreed in writing by Assignor and Assignee as to any specific roadway or roadways.

In the event any roadway or roadways used by Assignee interferes with the sale, lease, use or enjoyment of other portions of the land owned by Assignor, Assignee agrees to relocate such roadway or roadways at its expense upon request therefor by Assignor.

3. The Assignee shall have all the rights and benefits and all of the obligations under the geothermal lease to be issued by the State except as herein provided, and will at its sole cost and expense apply for such lease together with any other approvals required to commence its mining for geothermal resources on the land. Assignee agrees after termination or expiration of this Agreement to leave said land in a clean condition and to level sump holes or excavations. Assignee shall remain responsible for any wells drilled on the land which responsibility shall survive

the expiration or sooner termination of this Agreement.

4. Upon the violation of any of the terms or conditons of this Agreement by the Assignee and the failure to remedy the same within ninety (90) days after written notice from the Assignor specifying such default and requesting remedying thereof, or upon default in performance of Assignee's obligations under the geothermal lease issued by the State, and such lease is terminated, then, at the option of the Assignor, this Agreement shall forthwith cease and terminate, and all rights of the Assignee in and to said land be at an end, provided however, that to the extent the lease issued by the State is kept in force, Assignee shall continue to have the rights and obligations hereunder as to such land area surrounding each well producing or being drilled and in respect to which Assignee shall not be in default and which land area was previously approved by Assignor for Assignee's use, and saving and excepting rights of way, easements and surface areas necessary for Assignee's operating and for maintenance and operation of electric generating and power transmission facilites and other facilities for utilization of processing of other products covered hereby, and as to which the person or persons owning or operating such facilities are not in default under the agreement or agreements made with Assignor pursuant to which such facilities were installed on the land and rights of way and easements granted. Assignee may, at any time before or after such default, and upon payment of the sum of TEN AND NO/100 FOLLARS ($10.00) to the Assignor as and for fixed and liquidated damages, surrender to the Assignor all of the right, title and interest of Assignee in and to the land or

any part thereof, and except for any monies owing to Assignor, thereupon all rights and obligations of the parties hereto one to the other shall thereupon cease and terminate as to the premises surrendered.

5. This agreement is subject to Assignee obtaining within twenty-four (24) months from the date hereof a lease of the subsurface geothermal resources of the land from the State of Hawaii. In the event that Assignee does not obtain such lease within such period, then this Agreement shall terminate and neither party hereto shall have any further rights or obligations hereunder.

6. The Assignee agrees that the Assignor will have the right at its option to use all the water generated from any well or wells on the land excess of sales thereof to others and the needs of the Assignee.

7. The Assignee shall be diligent in the exploration or development of the geothermal resources on the land. Failure to perform diligent operations may subject this Agreement to termination by the Assignor. Diligent operations mean prompt applications for the geothermal lease from the State and other necessary governmental approvals and exploratory or development operations on the land, including without limitation geochemical surveys, heat flow measurements, core drilling, or drilling of wells for discovery, evaluation, or production of geothermal resources.

8. Assignee shall at all times maintain full and accurate records of production and payments relating to Assignee's operations and activities upon and in connection with said land. All books and records of leesee pertaining to or necessary in determining royalty payments shall be open to inspection at all reasonable times by the authorized representatives of the Assignor.

9. This Agreement and all its terms, conditions and provisions shall extend to and be binding upon the heirs, excutors, administrators, grantees, successors and assigns of the parties hereto.

TO HAVE AND TO HOLD, the same unto the said Assignee its successors and permitted assigns from and after the date hereof until expiration of said lease issued by the State or sooner termination as herein provided.

IN WITNESS WHEREOF, the parties hereto have caused these presents to be executed this 5th day of June 1978.

F. NEWELL BOHNETT

BY F. Newell Bohnett
Its

BY
Its

ASSIGNOR

PUUWAAWAA STEAM COMPANY

BY
Its Gen. Partner. Geothermal Exploration & Development Corp.

BY F. Newell Bohnett
Its Limited Partner.

ASSIGNEE